(12) UK Patent Application (19) GB (11) 2 342 394 (13) A

(43) Date of A Publication 12.04.2000

(21) Application No 9923523.6

(22) Date of Filing 05.10.1999

(30) Priority Data
(31) 10282385 (32) 05.10.1998 (33) JP

(51) INT CL[7]
F01L 1/053 , F02B 75/24

(52) UK CL (Edition R)
F1B B1B3 B2P1A1 B2P1A4 B2P16 B2P2P

(56) Documents Cited
US 4223647 A US 3989016 A

(58) Field of Search
UK CL (Edition Q) F1B B2P1A1 B2P1A4
INT CL[6] F01L 1/047 1/053
online: EPODOC, JAPIO, WPI

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(54) Abstract Title

I.c. engine with offset intake and exhaust valves operated directly by a single overhead camshaft

(57) An engine in which combustion chambers are formed between pistons slidably fitted in cylinder bores and a cylinder head, a cam shaft is linked with intake valves and exhaust valves for respectively opening/closing intake passages and exhaust passages provided in the cylinder, and a transmission mechanism is provided between the crank shaft and the cam shaft, wherein the intake valves and the exhaust valves can be opened/closed with an extremely simple mechanism. To this end, intake valves 36_L or 36_R and exhaust valves 37_L or 37_R are disposed in parallel at positions offset to one side from a plane 38_L or 38_R passing through the axial lines of cylinder bores 21_L or 21_R and the axial line of a crank shaft 29; and cams 48_L and 49_L or 48_R and 49_R for directly opening/closing the intake valves 36_L or 36_R and the exhaust valves 37_L or 37_R are provided on the cam shaft 46_L or 46_R which is disposed in parallel to the crank shaft (29) in such a manner as to common to the intake valves 36_L or 36_R and the exhaust valves 37_L or 37_R.

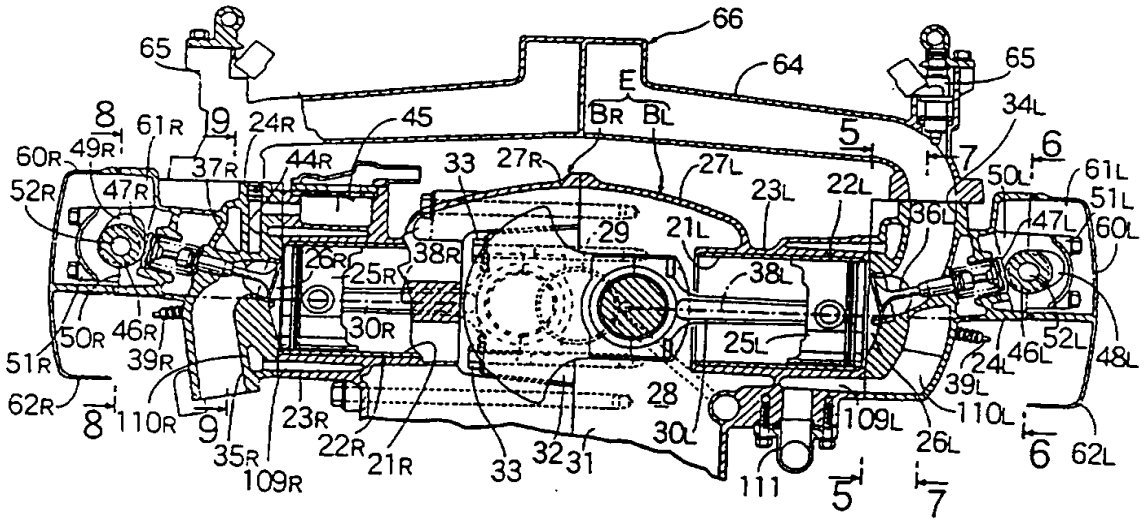

FIG. 4

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FIG. 1

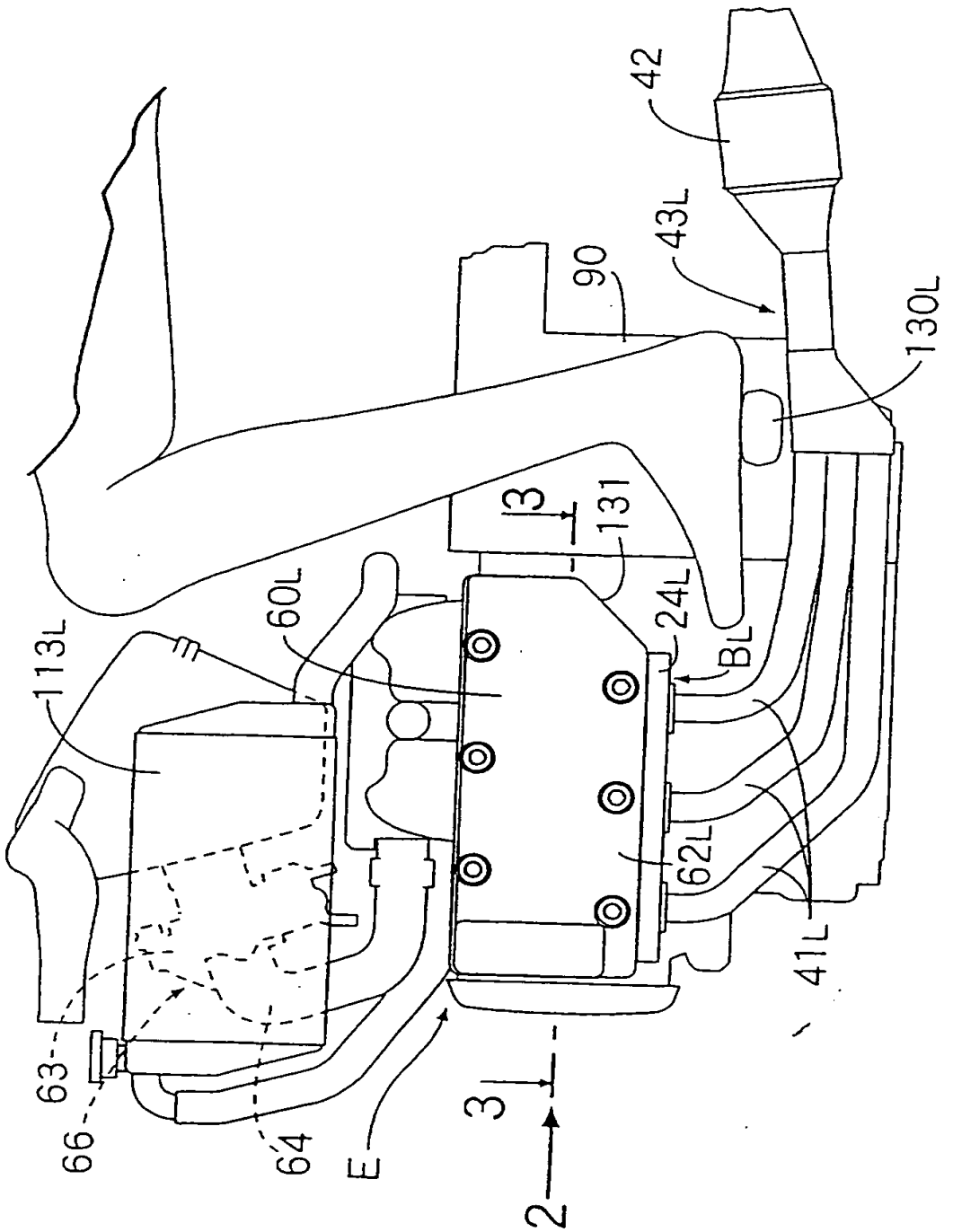


FIG. 2

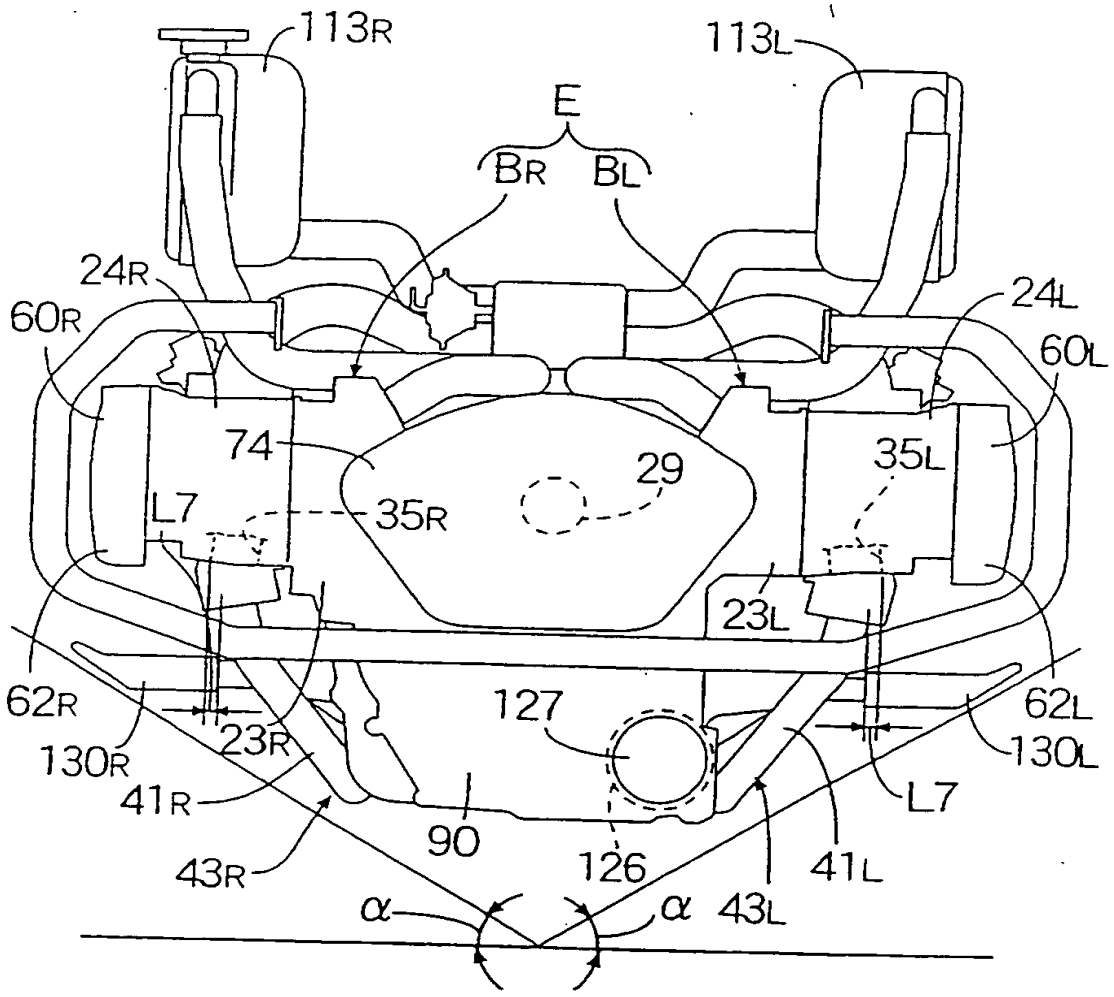
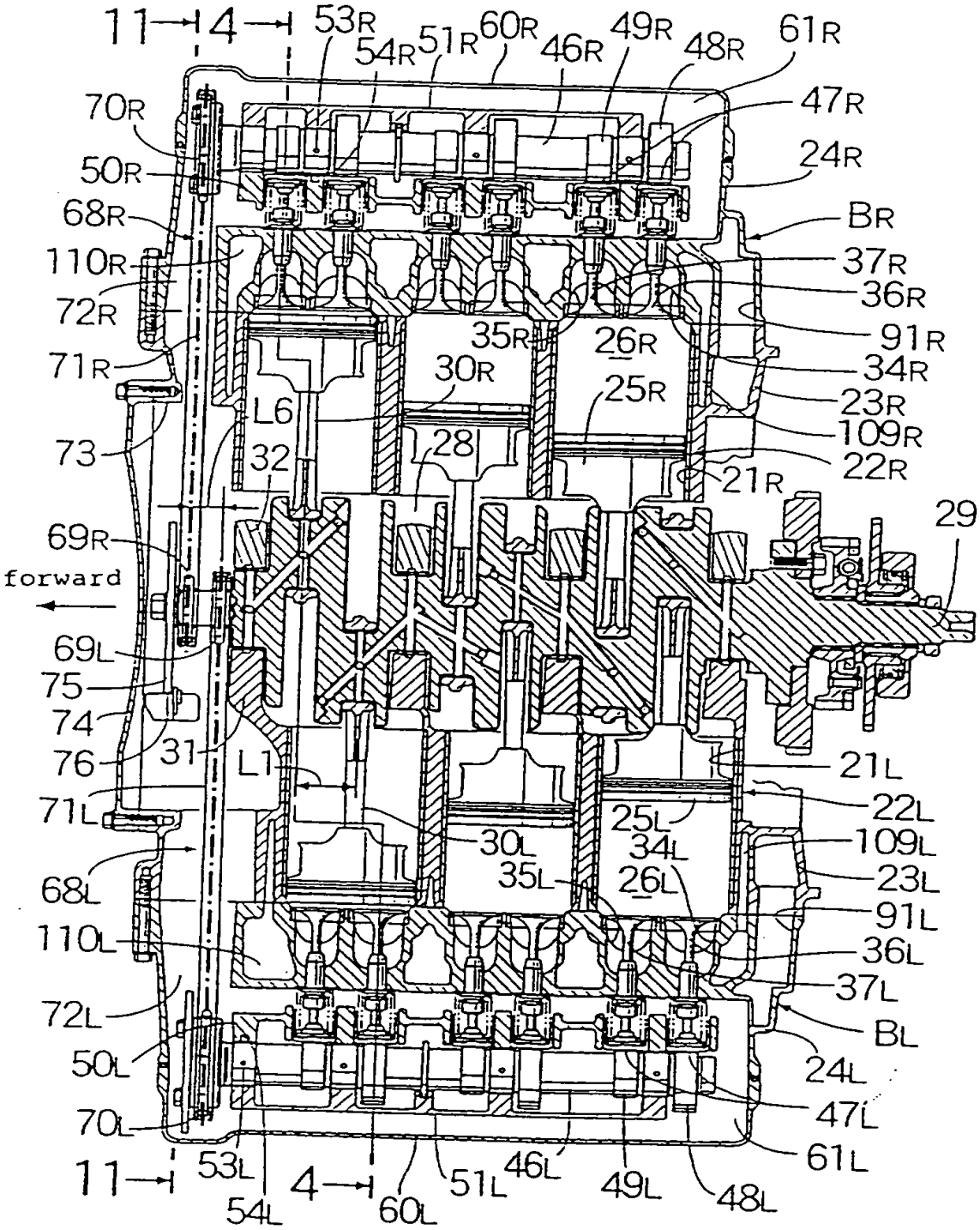


FIG. 3



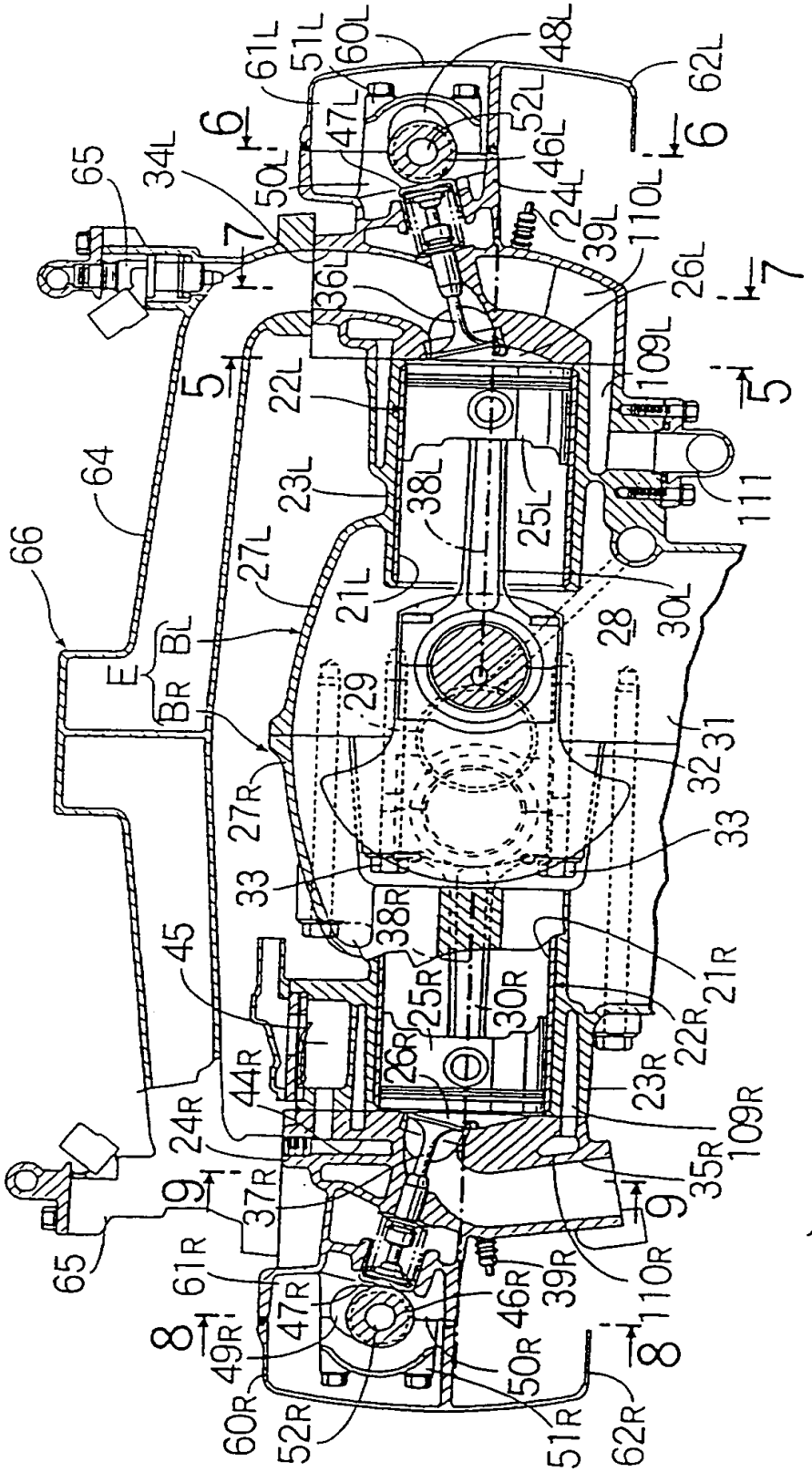


FIG. 4

FIG. 5

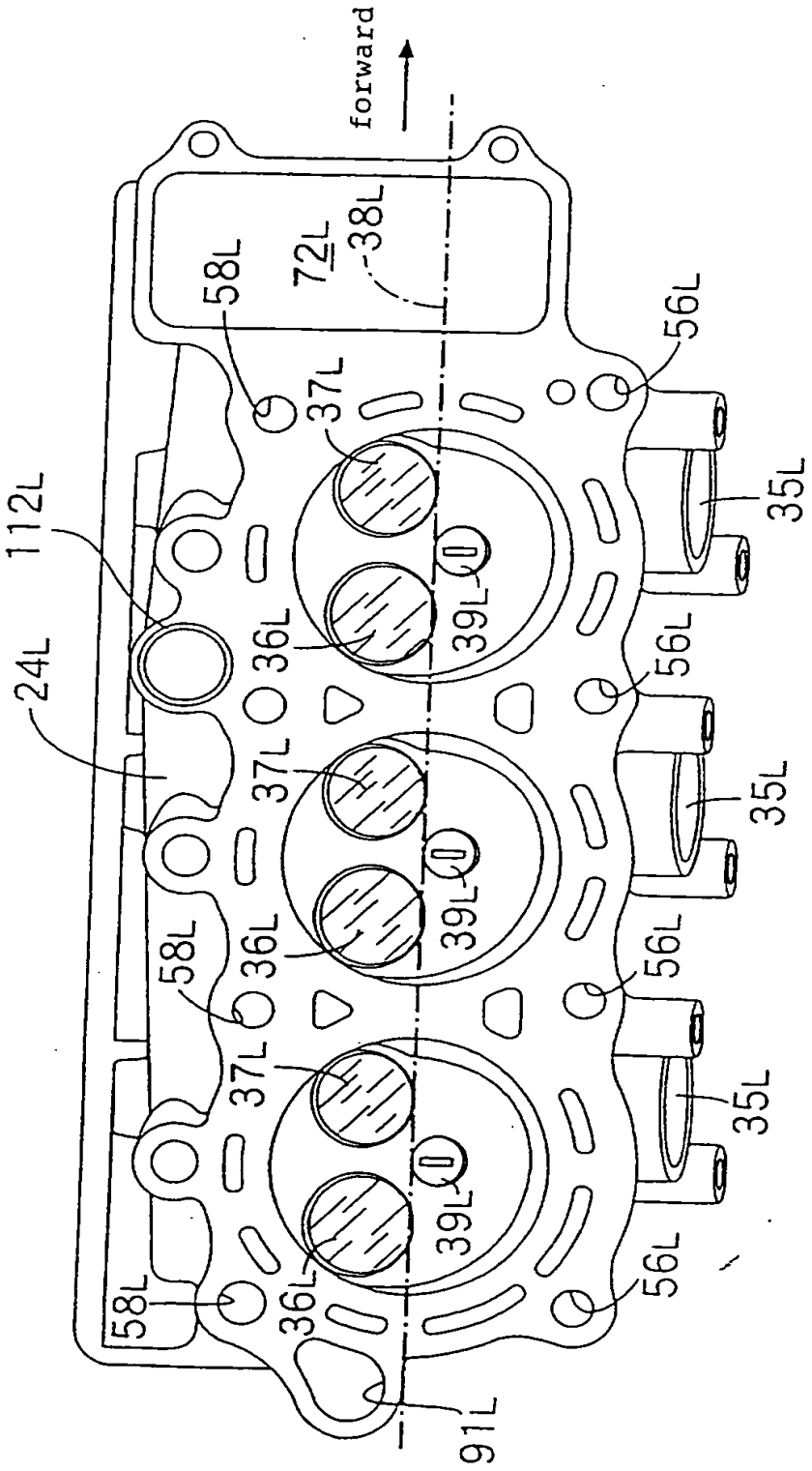


FIG. 6

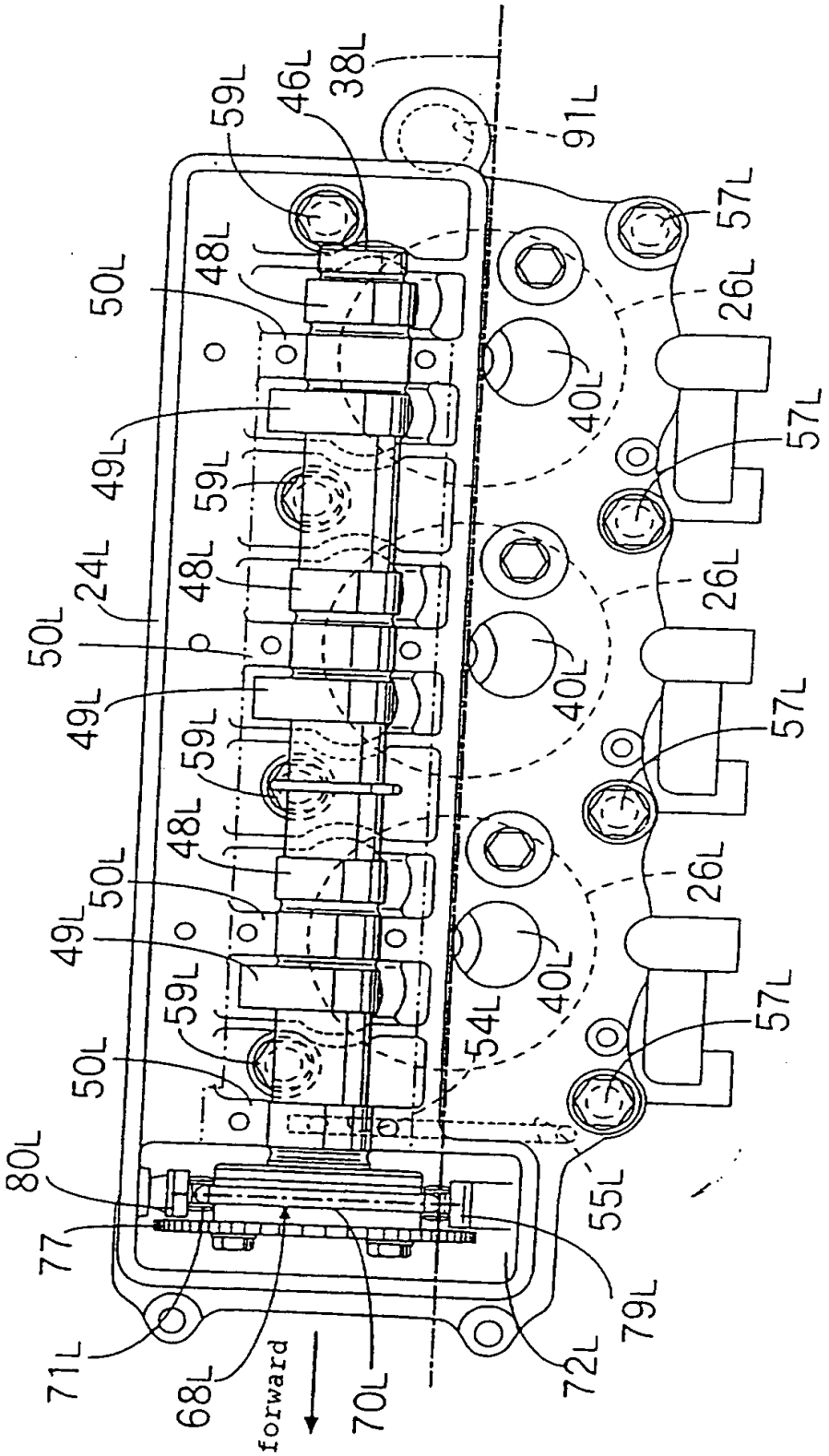


FIG. 7

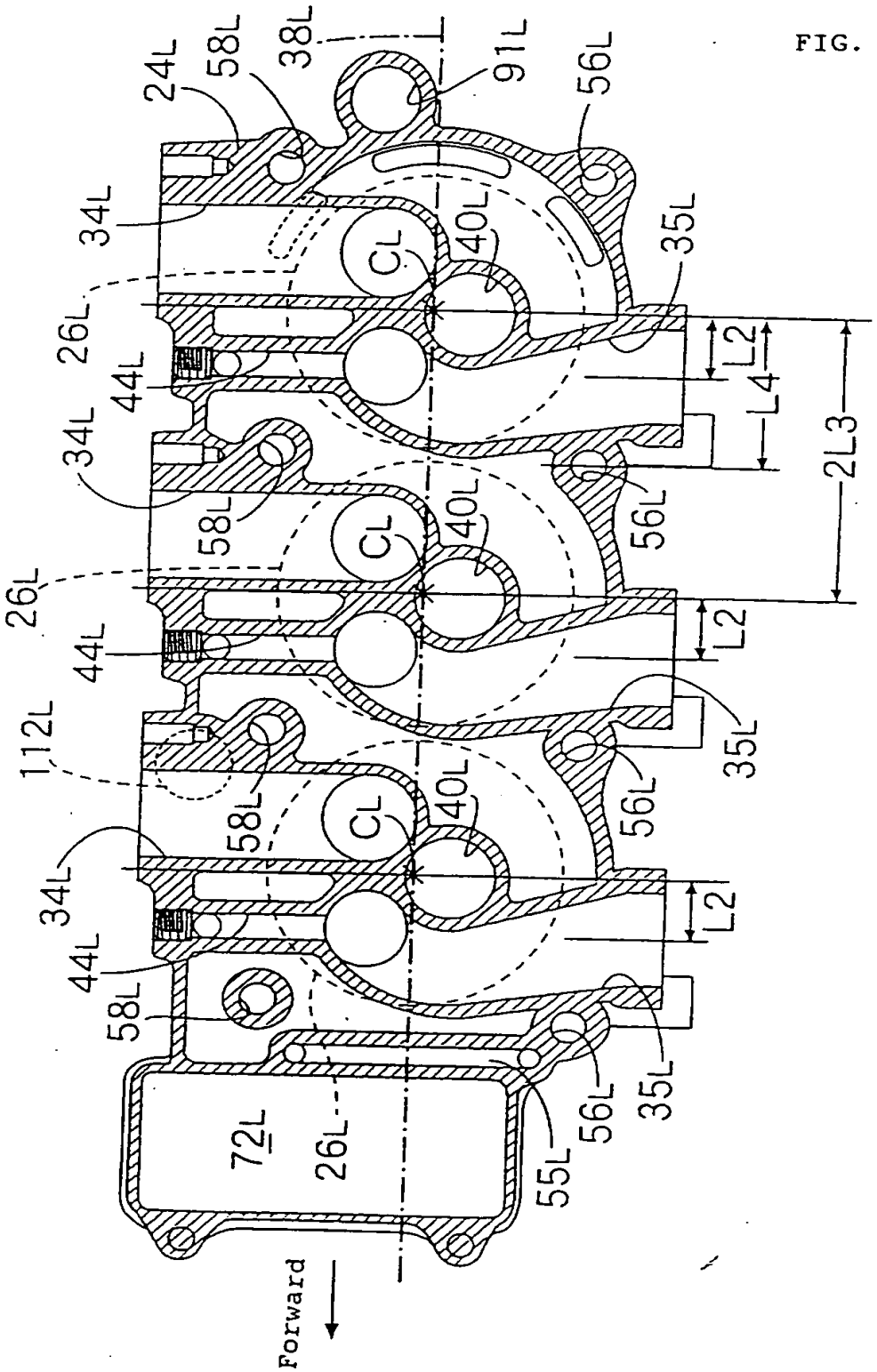


FIG. 8

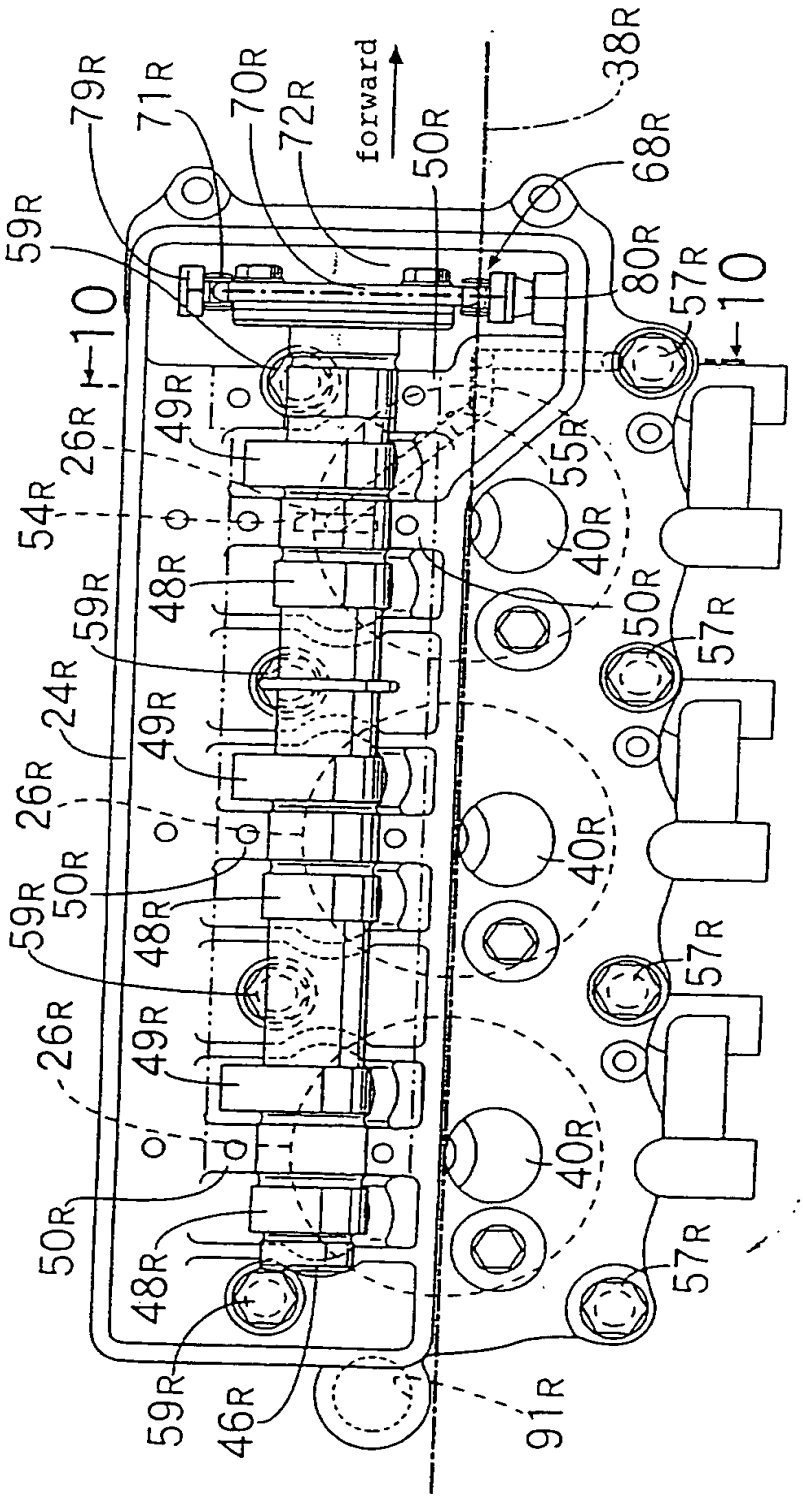


FIG. 9

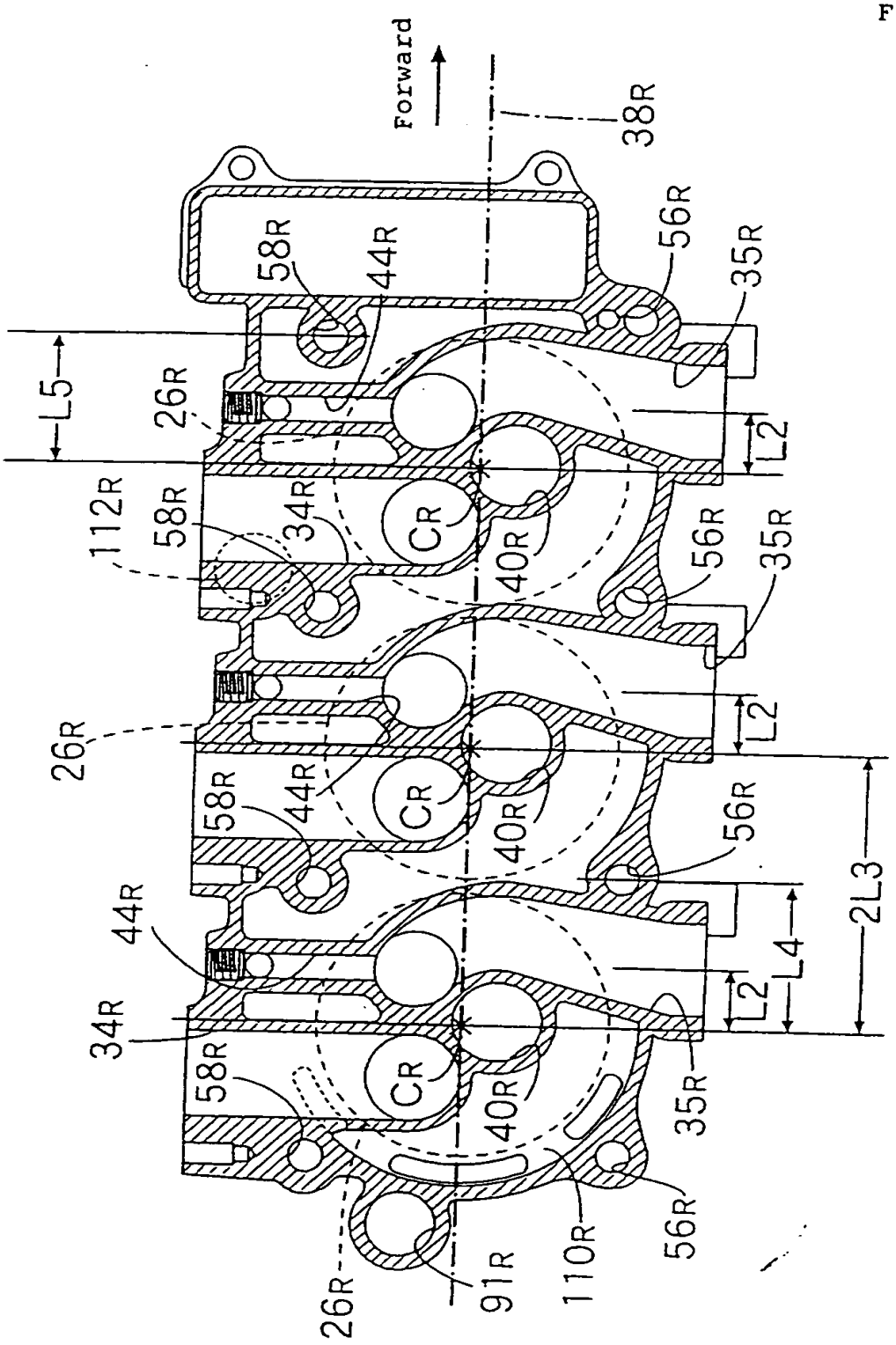


FIG. 10

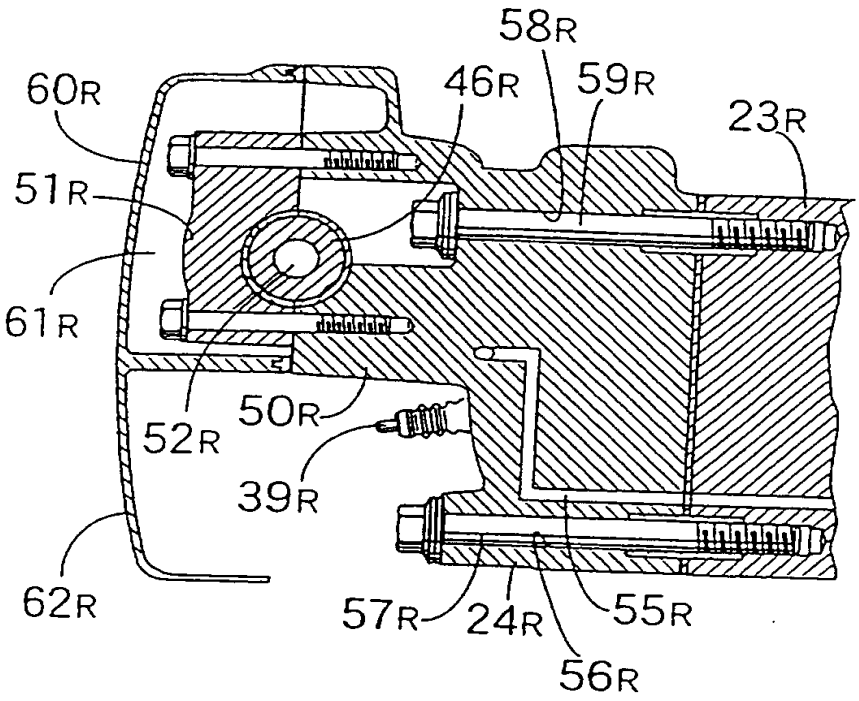


FIG. 11

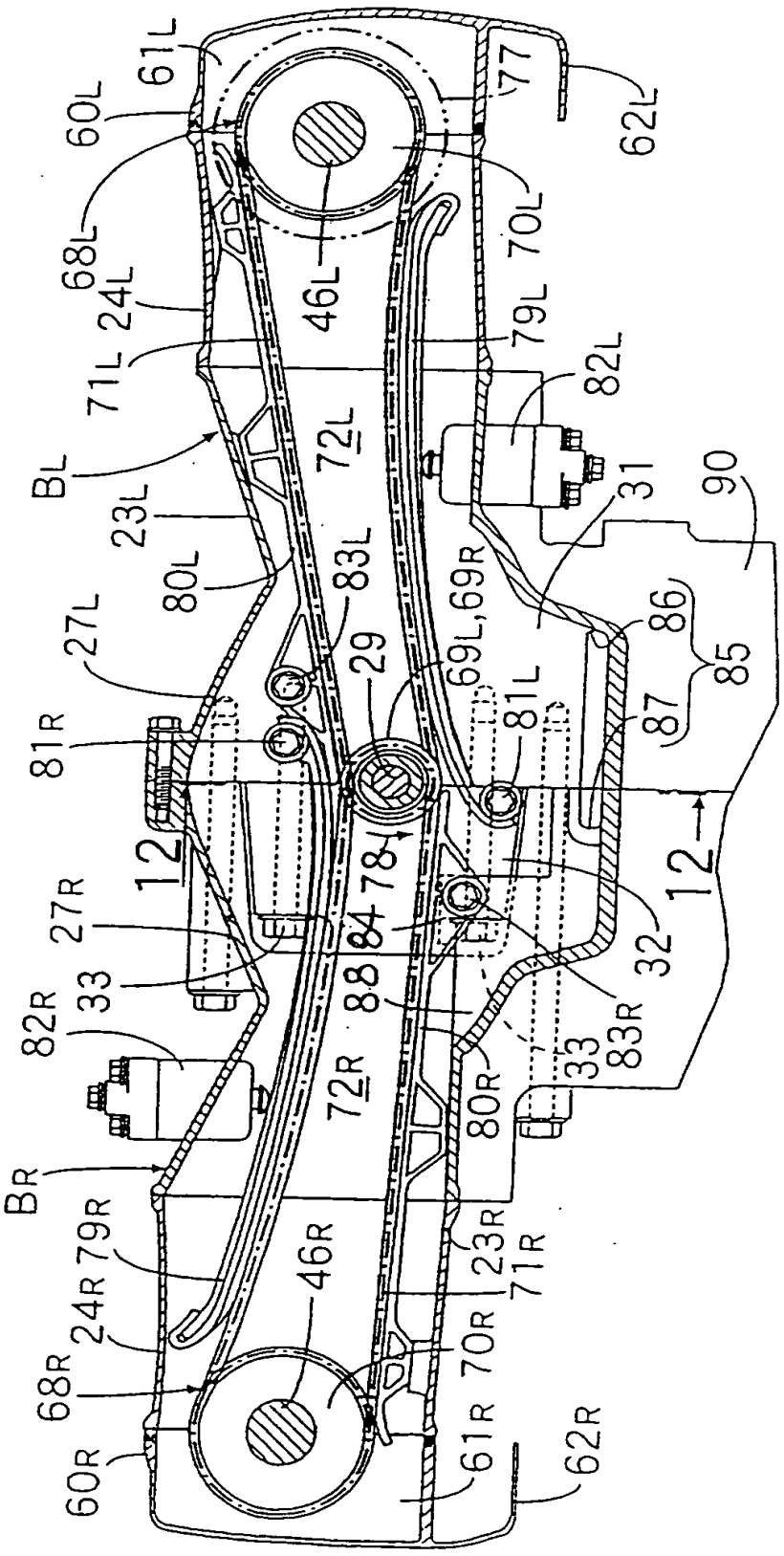


FIG. 12

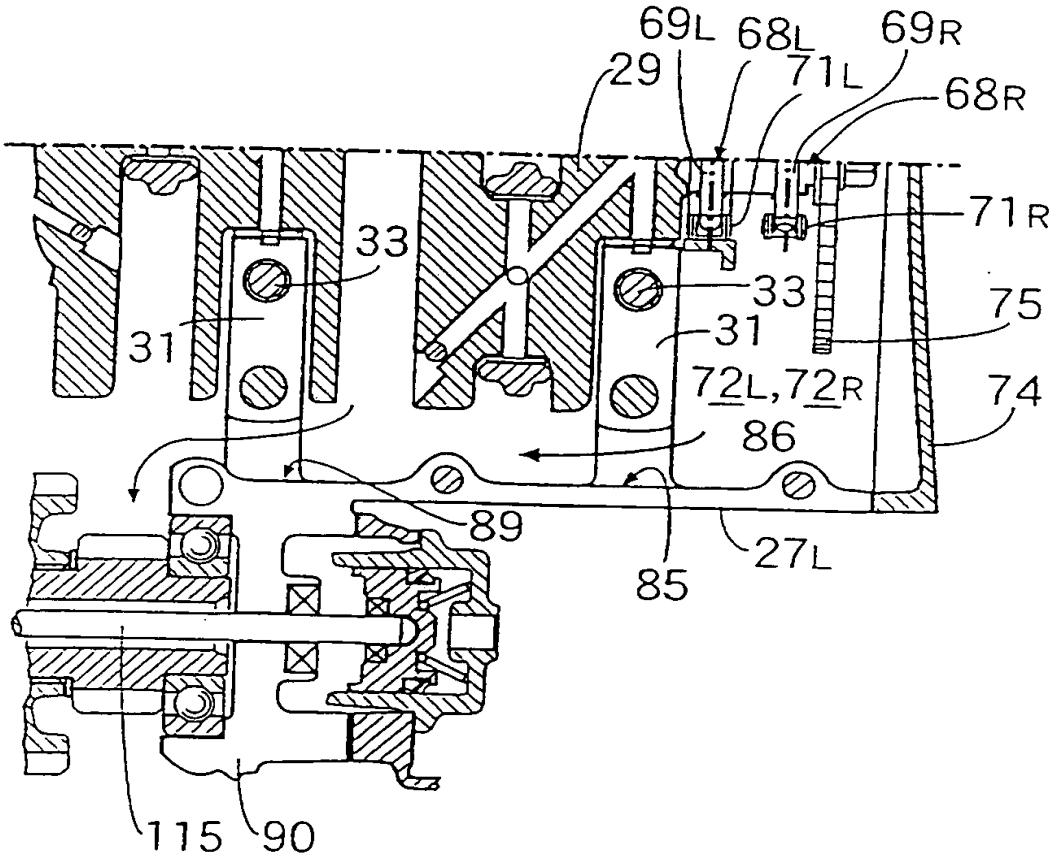


FIG. 13

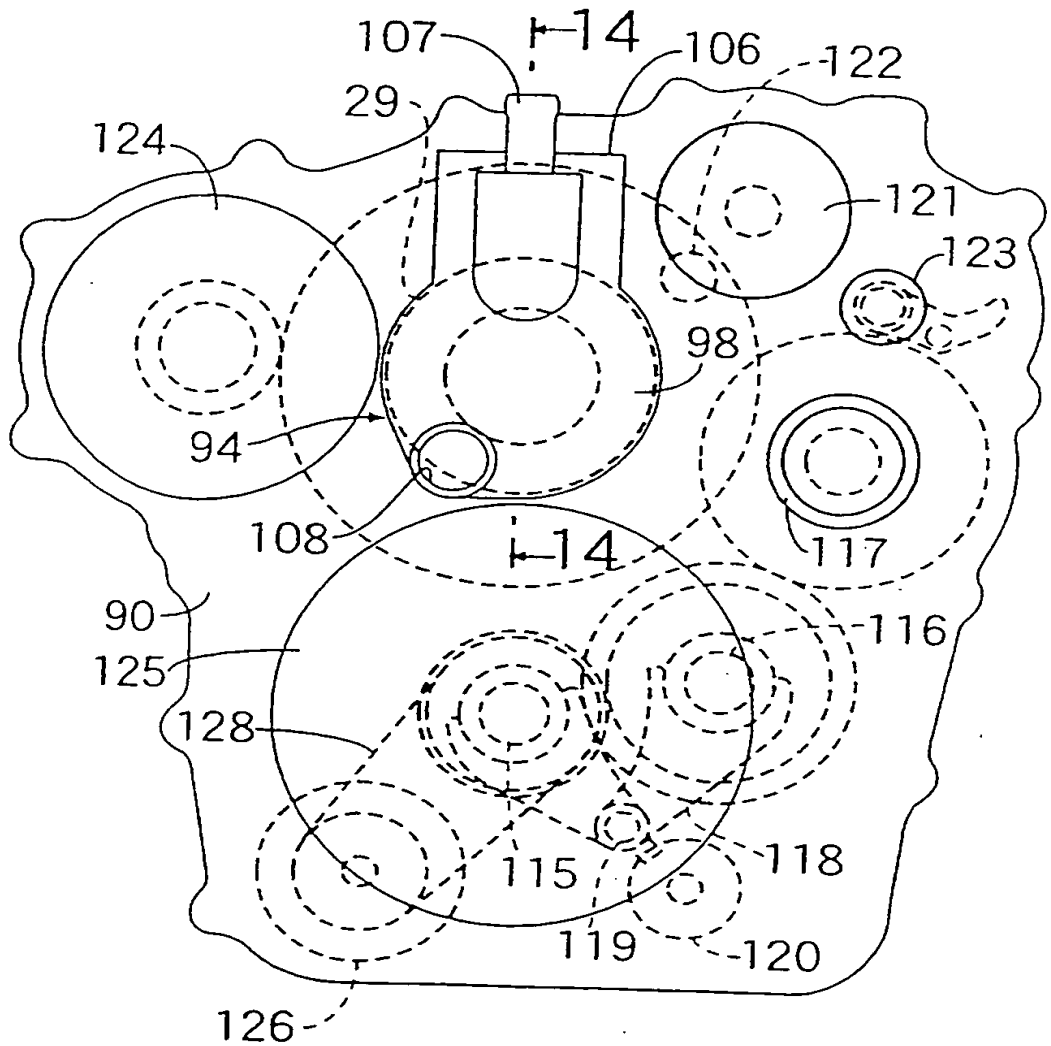
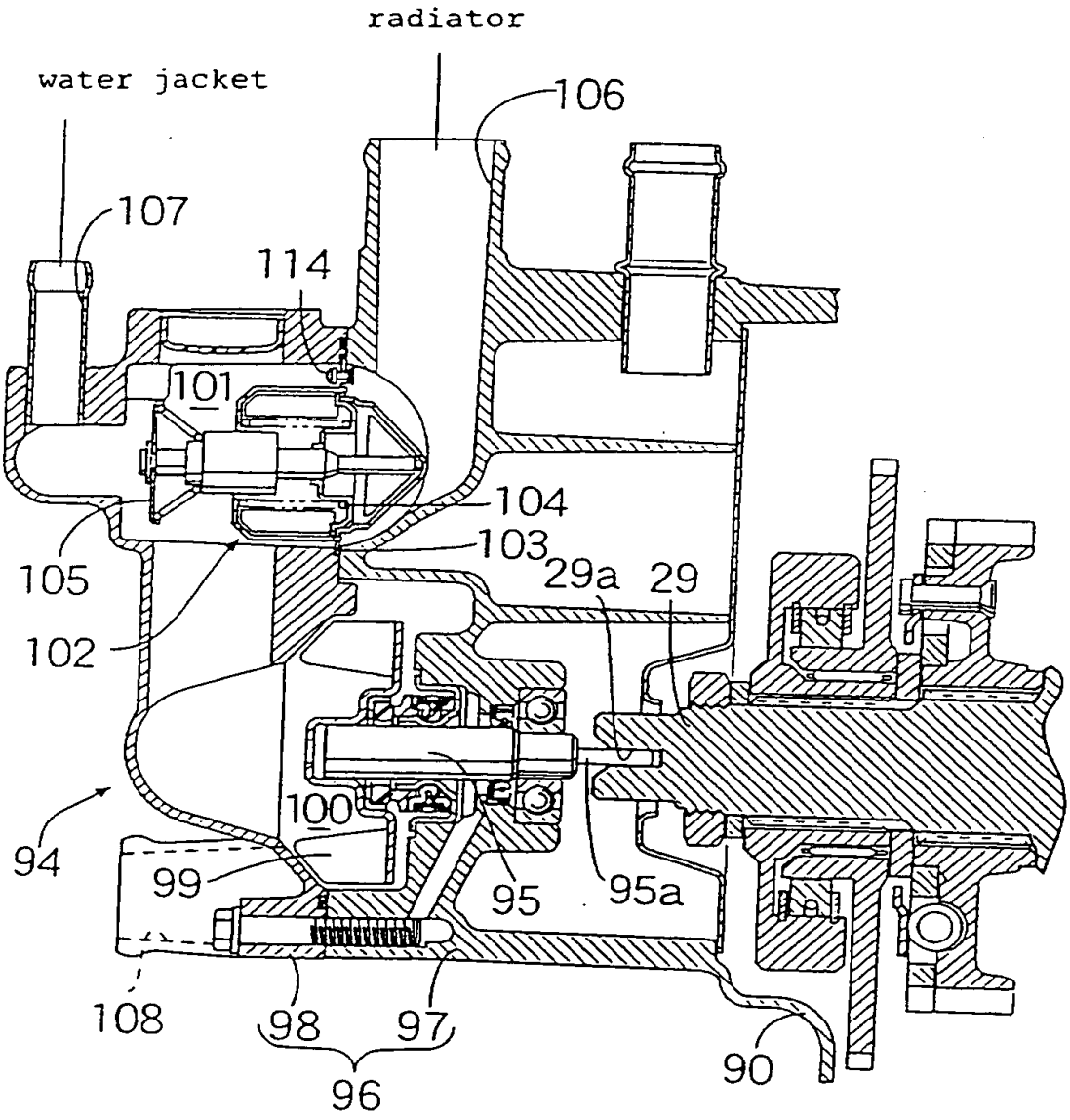


FIG. 14



ENGINE

The present invention relates to an engine in which combustion chambers are formed between pistons slidably fitted in cylinder bores provided in a cylinder block and a cylinder head; a cam shaft is linked with intake valves and exhaust valves for respectively opening/closing intake passages and exhaust passages which are provided in the cylinder head in such a manner as to be communicated to the combustion chambers; and a transmission mechanism for reducing a rotational power of a crank shaft to a half and transmitting the reduced rotational power to the cam shaft is provided between the crank shaft and the cam shaft.

The engine of this type has been disclosed, for example, in Japanese Utility Model Laid-open No. Sho 63-65811. In this engine, the rotational motion of a single cam shaft is converted into a linear motion for opening/closing intake valves and exhaust valves via individual rocker arms, or intake valves and exhaust valves are opened/closed by a pair of cam shafts individually provided for the intake valves and exhaust valves.

The prior art engine, in which the intake valves and exhaust valves are opened/closed by the above mechanism, requires the rocker arms or the cam shafts to be individually provided for the intake valves and the exhaust valves. This causes a problem in that it is difficult to simplify the configuration of a valve system mechanism for opening/closing the intake valves and the exhaust valves.

According to the present invention, there is provided an engine in which combustion chambers are formed between pistons slidably fitted in cylinder bores provided in a cylinder block and a cylinder head; a cam shaft is linked with intake valves and exhaust valves

for respectively opening/closing intake passages and exhaust passages which are provided in the cylinder head in such a manner as to be communicated to the combustion chambers; and a transmission mechanism for reducing the rotational speed of a crank shaft to a half and transmitting the reduced rotational speed to the cam shaft is provided between the crank shaft and the cam shaft; wherein the intake valves and the exhaust valves are disposed in parallel at positions offset to one side from a plane passing through the axial lines of the cylinder bores and the axial line of the crank shaft; and cams for directly opening/closing the intake valves and the exhaust valves are provided on the cam shaft which is disposed in parallel to the crank shaft in such a manner as to be common to the intake valves and the exhaust valves.

With this configuration, since the intake valves and the exhaust valves can be directly opened/closed by the cam shaft common thereto, it is possible to significantly simplify the configuration of the valve system mechanism for opening/closing the intake valves and the exhaust valves.

Preferably, on the opposed side to the disposition side of the intake valves and the exhaust valves with respect to the plane, ignition plugs are mounted on the cylinder head in such a manner as to face to the central portions of the combustion chambers. With this configuration, it is possible to easily dispose the ignition plugs in such a manner as to face to the central portions of the combustion chambers without interference with the intake valves and the exhaust valves.

A further preferred configuration is for the intake passages and the exhaust passages are opened to side surfaces of the cylinder head on both sides of the plane, respectively. With this configuration, an intake system and an exhaust system can be easily connected to

the cylinder head.

Preferably, in addition to this configuration of the intake passages and the exhaust passages, the passages opened to the side surface of the cylinder head on the opposed side to the disposition side of the intake valves and the exhaust valves with respect to the plane are curved and swelled on one end side of the cam shaft in such a manner as to bypass the ignition plugs which are mounted in the cylinder head in such a manner as to face to the combustion chambers. With this configuration, it is possible to smoothly dispose the ignition plugs in such a manner as to face to the central portions of the combustion chambers without interference with the intake passages and the exhaust passages.

In addition to this feature, the arrangement may be such that on the opposed side to the disposition side of the intake valves and the exhaust valves with respect to the plane, the cylinder head has a plurality of through-holes including those each of which is disposed at a corresponding portion between the adjacent combustion chambers, the plurality of through-holes being spaced at intervals in the axial direction of the cam shaft in such a manner as to allow fastening bolts for fastening the cylinder head to the cylinder block to pass therethrough; and a distance between a center of one of the through-holes adjacent to the associated one of the passages bypassing the ignition plugs on the one side of the cam shaft and a center of one of the combustion chambers associated with the passage is set to be larger than a half of a distance between the centers of the adjacent combustion chambers.

In the case where the through-holes allowing the fastening bolts for fastening the cylinder head to the cylinder block are provided in such a manner as to be adjacent to the passages bypassing the ignition plugs on the one end side of the cam shaft, the passages are

required to be curved in such a manner as to avoid the through-holes. In this regard, it is possible to dispose the through-holes in such a manner as to make the curving of the passages small and hence to suppress the flow resistance in the passages.

The arrangement may alternatively be such that on the disposition side of the intake valves and the exhaust valves with respect to the plane, the cylinder head has a plurality of through-holes including those each of which is disposed between adjacent combustion chambers, the plurality of through-holes being spaced at intervals in the axial direction of the cam shaft in such a manner as to allow fastening bolts for fastening the cylinder head to the cylinder block; and a distance between a center of one of the through-holes disposed at the outermost end on the one end side of the cam shaft and the center of one of the combustion chambers disposed at the outermost end on the one end side of the cam shaft is set to be smaller than a half of a distance between the centers of the adjacent combustion chambers.

With this configuration, it is possible to make the end portion of the cylinder head on the one end side of the cam shaft as close to the center of the cylinder bore disposed at the outermost end on the one end side of the cam shaft, that is, on the curved side of the passages bypassing through the ignition plugs as possible, and hence to make the length of the cylinder head in the axial direction of the cam shaft as short as possible.

In one form of the invention, the axial lines of the cylinder bores discussed above are disposed substantially in the horizontal direction; a valve system chamber is formed between the cylinder head and a head cover in such a manner as to contain the cam shaft offset upwardly from the plane; one end of a transmission chamber for containing the transmission mechanism is communicated to the valve system chamber,

the transmission mechanism being configured such that an endless chain is wound around a drive sprocket fixed on the one end of the crank shaft and a driven sprocket fixed on the one end of the cam shaft; and the lower portion of the other end of the transmission chamber is communicated into a crank case.

With this configuration, since the transmission mechanism performs power transmission via the chain, oil is allowed to flow in the transmission chamber containing the transmission mechanism; and since the cam shaft is disposed over the crank shaft, oil in the valve system chamber is allowed to flow toward the crank shaft at the lower level in the transmission chamber, with a result that it is possible to easily return the oil in the valve system chamber to the crank case side. Further, since the ignition plugs on the opposed side of the disposition side of the intake valves and the exhaust valves with respect to the above plane are disposed at the lower portion of the cylinder head, it becomes easy to discharge water having permeated near the ignition plugs on the outer surface side of the cylinder head.

In another preferred form of the invention, the engine is mounted in a vehicle, for example a motorcycle in such a manner that a plurality of the cylinder bores are disposed in parallel with the axial lines thereof extending substantially in the horizontal direction; a pair of cylinder bore rows are oppositely disposed on both the sides of the crank shaft; a plurality of the intake valves and a plurality of the exhaust valves are disposed in parallel in such a manner as to be offset upwardly from the plane for each of the cylinder bore rows; and the one end of the crank shaft in the axial direction is disposed on the front side of the vehicle. In a motorcycle having this configuration, since the cam shaft is disposed over the axial line of each cylinder bore row and the passages bypassing the

ignition plugs are curved forwardly, it is easy to ensure a space allowing the driver to extend her/his feet forwardly in a lower rear portion of the horizontally-opposed engine mounted on the vehicle.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings:

Fig. 1 is a side view of a horizontally-opposed type engine mounted on a motorcycle;

Fig. 2 is a front view seen along an arrow 2 of Fig. 1;

Fig. 3 is an enlarged sectional view taken on line 3-3 of Fig. 1;

Fig. 4 is a sectional view taken on line 4-4 of Fig. 3;

Fig. 5 is an enlarged view seen along line 5-5 of Fig. 4;

Fig. 6 is an enlarged view seen along line 6-6 of Fig. 4;

Fig. 7 is an enlarged sectional view taken on line 7-7 of Fig. 4;

Fig. 8 is an enlarged view seen along line 8-8 of Fig. 4;

Fig. 9 is an enlarged sectional view taken on line 9-9 of Fig. 4;

Fig. 10 is a sectional view taken on line 10-10 of Fig. 8;

Fig. 11 is a sectional view taken on line 11-11 of Fig. 3;

Fig. 12 is a sectional view taken on line 12-12 of Fig. 11;

Fig. 13 is a schematic view, seen from the rear side, of a mission case; and

Fig. 14 is an enlarged sectional view taken on line 14-14 of Fig. 13.

Referring first to Figs. 1 and 2, a four-cycle/multi-cylinder (e.g., six-cylinder)

horizontally-opposed type engine is mounted on a motorcycle. An engine main body E of the engine includes a left engine block B_L disposed on the left side in a state that the motorcycle is directed forwardly in the running direction thereof, and a right engine block B_R disposed on the right side in a state that the motorcycle is directed forwardly in the running direction thereof.

Referring particularly to Figs. 3 and 4, the left engine block B_L includes a left cylinder block 23_L and a left cylinder head 24_L connected to the left cylinder block 23_L. The left cylinder block 23_L has a left side cylinder bore row 22_L including a plurality (e.g., three) of cylinder bores 21_L disposed in parallel. The left cylinder head 24_L has combustion chambers 26_L each of which is formed between the associated one of the cylinder bores 21_L and a piston 25_L slidably fitted in the cylinder bore 21_L. A left crank case 27_L is formed integrally with the side, opposed to the left cylinder head 24_L, of the cylinder block 23_L. The right engine block B_R includes a right cylinder block 23_R and a right cylinder head 24_R connected to the right cylinder block 23_R. The right cylinder block 23_R has a right side cylinder bore row 22_R including a plurality (e.g., three) of cylinder bores 21_R disposed in parallel. The right cylinder head 24_R has combustion chambers 26_R each of which is formed between the associated one of the cylinder bores 21_R and a piston 25_R slidably fitted in the cylinder bore 21_R. A right crank case 27_R is formed integrally with the side, opposed to the right cylinder head 24_R, of the cylinder block 23_R.

The left and right engine blocks B_L and B_R are opposed to each other with the axial lines of the cylinder bores 21_L and 21_R directed substantially in the horizontal direction. The left crank case 27_L of the left engine block B_L is fastened to the right crank case 27_R of the right engine block B_R in such a manner as to

form a crank chamber 28 therebetween.

The pistons 25_L and 25_R in the left and right engine blocks B_L and B_R are commonly connected to a crank shaft 29 via connecting rods 30_L and 30_R, respectively. The crank shaft 29 is disposed such that its one end side is located on the front side of the motorcycle in the longitudinal direction of the motorcycle and its axial line extends in the longitudinal direction of the motorcycle. The crank shaft 29 is supported by one of the left and right crank cases 27_L and 27_R (left crank case 27_L in this embodiment). To be more specific, the crank case 29 is rotatably supported by journal walls 31 integrally formed on the left crank case 27_L at a plurality of locations spaced in the axial line direction of the crank shaft 29 and bearing caps 32 each of which is fastened to the associated one of the journal walls 31 with a pair of bolts 33.

Each of the cylinder bores 21_R constituting the cylinder bore row 22_R on the right engine block B_R side is offset forwardly in the longitudinal direction of the motorcycle from the associated one of the opposed cylinder bores 21_L constituting the cylinder bore row 22_L on the left engine block B_L side by a first offset amount L1.

Referring particularly to Figs. 5 , 6 and 7, the left cylinder head 24_L includes pairs of intake passages 34_L and exhaust passages 35_L communicated to the combustion chambers 26_L, each pair being provided for the associated one of the combustion chambers 26_L. The left cylinder head 24_L also includes intake valves 36_L each being adapted to open/close the associated one of the intake passages 34_L and exhaust valves 37_L each being adapted to open/close the associated one of the exhaust passages 35_L.

The intake valves 36_L and the exhaust valves 37_L, which extend in the direction parallel to the axial line of the crank shaft 29, are offset upwardly from a plane

38_L passing through the axial lines of the cylinder bores 21_L and the axial line of the crank shaft 29 in such a manner that the exhaust valves 37_L are offset forwardly from the intake valves 36_L in the longitudinal direction of the motorcycle. The left cylinder head 24_L also includes ignition plugs 39_L each of which faces to the central portion of the associated one of the combustion chambers 26_L at a position which is located between the associated one of the pairs of the intake valves 36_L and exhaust valve 37_L on the opposed side to the disposition side of the intake valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the lower side from the plane 38_L.

Each of the intake valves 36_L and the exhaust valves 37_L is mounted to the left cylinder head 24_L in such a manner as to be tilted at an acute angle with respect to the plane 38_L. On the opposed side to the disposition side of the intake valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the lower side from the plane 38_L, the left cylinder head 24_L has plug mounting holes 40_L for mounting the ignition plugs 39_L in a state that the ignition plugs 39_L is tiled at an acute angle with respect to the plane 38_L. That is to say, the ignition plugs 39_L are mounted to the left cylinder head 24_L in such a manner as to be tilted downwardly with respect to the plane 38_L.

On the projection chart crossing the axial lines of the cylinder bores 21_L at right angles, the intake passages 34_L are provided in the left cylinder head 24_L in such a manner as to cross the plane 38_L substantially at right angles, and are opened to one side surface of the left cylinder head 24_L on the disposition side of the intake valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the upper side from the plane 38_L. The exhaust passages 35_L are opened to the other side surface of the left cylinder head 24_L on the opposed side of the disposition side of the intake

valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the lower side from the plane 38_L. To be more specific, the exhaust passages 35_L are curved to be swelled toward one end side of the crank shaft 29 or the front side of the motorcycle in order to bypass the ignition plugs 39_L, that is, the plug mounting holes 40_L for mounting the ignition plugs 39_L.

Each of the exhaust passages 35_L is formed in such a manner as to be tilted downwardly toward the central portion of the motorcycle in the width direction and to be opened to the other side surface, that is, the lower surface of the left cylinder head 24_L. An exhaust system 43_L is provided which is composed exhaust pipes 41_L each of which is communicated to the associated one of the exhaust passages 35_L, a catalyst converter 42, an exhaust muffler (not shown), and the like. Each of the exhaust pipes 41_L of the exhaust system 43_L is tilted in such a manner as to get closer to the central portion of the motorcycle in the width direction as being separated apart downwardly from the left cylinder head 24_L, and is connected to an opening at the outer end of the associated one of the exhaust passages 35_L.

The center of the opening at the outer end of each exhaust passage 35_L is offset forwardly in the longitudinal direction of the motorcycle from a center C_L of the associated one of the combustion chambers 26_L by a second offset amount L2.

A single cam shaft 46_L, which is in parallel to the crank shaft 29 and has the axial line perpendicular to the axial lines, that is, the opening/closing operational lines of the intake valves 36_L and the exhaust valves 37_L, is disposed on the disposition side of the intake valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the upper side from the plane 38_L. On the other hand, the upper ends of the intake valves 36_L and the exhaust valves 37_L biased in the valve closing direction, that is, upwardly by

springs are in contact with valve lifters 47_L which are supported by the left cylinder head 24_L slidably in the operational axial lines of the valves 36_L and 37_L. The cam shaft 46_L includes intake side cams 48_L being in contact with those of the valve lifters 47_L associated with the intake valves 36_L, and exhaust side cams 49_L being in contact with those of the valve lifters 47_L associated with the exhaust valves 37_L. In other words, the intake valves 36_L and the exhaust valves 37_L are directly opened/closed by the intake side cams 48_L and the exhaust side cams 49_L of the cam shaft 46_L, respectively.

A plurality (for example, four) of portions, spaced in the axial line direction, of the cam shaft 46_L are rotatably supported by cam bearing portions 50_L provided on the left cylinder head 24_L and a cam holder 51_L commonly fastened to the cam bearing portions 50_L. Of the four cam bearing portions 50_L, three are each provided on the left cylinder head 24_L in such a manner as to be disposed between the pair of the intake valves 36_L and the exhaust valves 37_L provided for each combustion chamber 26_L, and the remaining one is provided on the left cylinder head 24_L in such a manner as to be located outside the combustion chamber 26_L disposed at the outermost end on one end side of the cam shaft 46_L (front end side of the motorcycle).

An oil passage 52_L with its both ends closed is coaxially provided in the cam shaft 46_L. As shown in Fig. 3, the cam shaft 46_L has oiling holes 53_L at positions corresponding to the cam bearing portions 50_L. The oiling holes 53_L are formed in such a manner as to extend from inside to outside of the cam shaft 46_L. Accordingly, lubricating oil is supplied from the interior of the cam shaft 46_L to the cam bearing portions 50_L and the cam holder 51_L. Further, an oil groove 54_L facing to the outer surface of the cam shaft 46_L is provided in the cam bearing portion 50_L disposed at the

outermost end on the one end side of the cam shaft 46_L, and an oiling passage 55_L provided in the left cylinder head 24_L and the left cylinder block 23_L is communicated to the oil groove 54_L. Accordingly, oil is supplied from the oiling passage 55_L into the oil passage 52_L in the cam shaft 46_L via the oil groove 54_L and the oiling hole 53_L.

Each of the intake side cams 48_L and the exhaust side cams 49_L has an oiling hole (not shown) communicated to the oil passage 52_L in the cam shaft 46_L. The outer end of the oiling hole is opened to the outer surface of the associated one of the intake side cams 48_L and the exhaust side cams 49_L. Accordingly, lubricating oil is also supplied to a slide-contact portion between each of the intake side cams 48_L and the exhaust side cams 49_L and the valve lifters 47_L provided for each of the intake valves 36_L and the exhaust valves 37_L.

The left cylinder head 24_L is fastened at a plurality of locations to the left cylinder block 23_L. On the opposed side to the disposition side of the intake valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the lower side from the plane 38_L, the left cylinder head 24_L has a plurality (for example, four) of through-holes 56_L spaced in the axial line direction of the cam shaft 46_L. Of the four through-holes 56_L, two are each disposed between the adjacent one of combustion chambers 26_L. Fastening bolts 57_L for fastening the left cylinder head 24_L to the left cylinder block 23_L are to be inserted in the through-holes 56_L.

Each through-hole 56_L is adjacent, on one end side (left side in Fig. 7) of the cam shaft 46_L, to the associated one of the exhaust passages 35_L bypassing the ignition plugs 39_L provided for the combustion chambers 26_L. Such a through-hole 56_L has a positional relationship that a distance L4 between a center of the through-hole 56_L and a center C_L of the associated

combustion chamber 26_L is larger than a value L3 ($_L3?_L4$). The value L3 is half a distance (2_L3) between the centers C_L of the adjacent ones of the combustion chambers 26_L.

On the disposition side of the intake valves 36_L and the exhaust valves 37_L with respect to the plane 38_L, that is, on the upper side from the plane 38_L, the left cylinder head 24_L has a plurality (for example, four) of through-holes 58_L spaced in the axial line direction of the cam shaft 46_L. Of the four through-holes 58_L, two are each disposed between the adjacent ones of the combustion chambers 26_L. Fastening bolts 59_L for fastening the left cylinder head 24_L to the left cylinder block 23_L are to be inserted in the through-holes 58_L. Each through-hole 58_L, that is, fastening bolt 59_L is disposed at a position where it is partially covered with the cam shaft 46_L.

A left head cover 60_L is fastened to the left cylinder head 24_L in such a manner that a valve system chamber 61_L for containing the cam shaft 46_L and the cam holder 51_L is formed between the left head cover 60_L and the left cylinder head 24_L. Since the cam shaft 46_L is disposed upwardly from the plan 38_L containing the axial lines of the cylinder bores 21_L, the valve system chamber 61_L is also formed between the left head cover 60_L and the left cylinder head 24_L in such a manner as to be offset upwardly from the plane 38_L.

A cover portion 62_L is formed integrally with the left head cover 60_L. Portions, connected to the exhaust passages 35_L, of the exhaust pipes 41_L of the exhaust system 43_L and the ignition plugs 39_L disposed downwardly are covered from outside by the cover portion 62_L.

Referring particularly to Figs. 8 and 9, the right cylinder head 24_R includes pairs of intake passages 34_R and exhaust passages 35_R communicated to the combustion chambers 26_R, each pair being provided for the associated one of the combustion chambers 26_R. The right cylinder head 24_R also includes intake valves 36_R each being

adapted to open/close the associated one of the intake passages 34_R and exhaust valves 37_R each being adapted to open/close the associated one of the exhaust passages 35_R.

The intake valves 36_R and the exhaust valves 37_R, which extend in the direction parallel to the axial line of the crank shaft 29, are offset upwardly from a plane 38_R passing through the axial lines of the cylinder bores 21_R and the axial line of the crank shaft 29 in such a manner that the exhaust valves 37_R are offset forwardly from the intake valves 36_R in the longitudinal direction of the motorcycle. Ignition plugs 39_R, each of which faces to the central portion of the associated one of the combustion chambers 26_R, are mounted to the right cylinder head 24_R on the lower side from the plane 38_R.

Each of the intake valves 36_R and the exhaust valves 37_R is tilted at an acute angle with respect to the plane 38_R. On the lower side from the plane 38_L, the right cylinder head 24_R has plug mounting holes 40_R for mounting the ignition plugs 39_R in a state that the ignition plugs 39_R is tilted at an acute angle with respect to the plane 38_R. The ignition plugs 39_R are thus mounted to the right cylinder head 24_R in such a manner as to be tilted downwardly with respect to the plane 38_R.

On the projection chart crossing the axial lines of the cylinder bores 21_R at right angles, the intake passages 34_R are provided in the right cylinder head 24_R in such a manner as to cross the plane 38_R substantially at right angles, and are opened to one side surface of the right cylinder head 24_R on the upper side from the plane 38_R. The exhaust passages 35_R are opened to the other side surface of the right cylinder head 24_R on the lower side from the plane 38_R. To be more specific, the exhaust passages 35_R are curved to be swelled toward one end side of the crank shaft 29 in the axial direction or the front side of the motorcycle in order to bypass the

ignition plugs 39_R, that is, the plug mounting holes 40_R.

Each of the exhaust passages 35_R is formed in such a manner as to be tilted downwardly toward the central portion of the motorcycle in the width direction and to be opened to the lower surface of the right cylinder head 24_R. An exhaust system 43_R is provided which is composed exhaust pipes 41_R each of which is communicated to the associated one of the exhaust passages 35_R, a catalyst converter (not shown), an exhaust muffler (not shown), and the like. Each of the exhaust pipes 41_R of the exhaust system 43_R is tilted in such a manner as to get closer to the central portion of the motorcycle in the width direction as being separated apart downwardly from the right cylinder head 24_R, and is connected to an opening at the outer end of the associated one of the exhaust passages 35_R.

The center of the opening at the outer end of each exhaust passage 35_R is offset forwardly in the longitudinal direction of the motorcycle from a center C_R of the associated one of the combustion chambers 26_R by the second offset amount L2.

The upper ends of the intake valves 36_R and the exhaust valves 37_R biased in the valve closing direction by springs are in contact with valve lifters 47_R supported by the right cylinder head 24_R. Intake side cams 48_R being in contact with those of the valve lifters 47_R associated with the intake valves 36_R and exhaust side cams 49_R being in contact with those of the valve lifters 47_R associated with the exhaust valves 37_R are provided on a single cam shaft 46_R which is disposed on the upper side from the plane 38_R. The cam shaft 46_R is in parallel to the crank shaft 29 and has the axial line perpendicular to the opening/closing operational axial lines of the intake valves 36_R and the exhaust valves 37_R. In other words, the intake valves 36_R and the exhaust valves 37_R are directly opened/closed by the intake side cams 48_R and the exhaust side cams 49_R of the

cam shaft 46_R, respectively.

A plurality (for example, four) of portions, spaced in the axial line direction, of the cam shaft 46_R are rotatably supported by cam bearing portions 50_R provided on the right cylinder head 24_R and a cam holder 51_R commonly fastened to the cam bearing portions 50_R. Of the four cam bearing portions 50_R, three are each provided on the right cylinder head 24_R in such a manner as to be disposed between the pair of the intake valves 36_R and the exhaust valves 37_R provided for each combustion chamber 26_R, and the remaining one is provided on the right cylinder head 24_R in such a manner as to be located outside the combustion chamber 26_R disposed at the outermost end on one end side of the cam shaft 46_R (front end side of the motorcycle).

As shown in Fig. 3, the cam shaft 46_R has oiling holes 53_R at positions corresponding to the cam bearing portions 50_R. The oiling holes 53_R are formed in such a manner as to extend from inside to outside of the cam shaft 46_R. Lubricating oil is supplied from an oil passage 52_R formed in the cam shaft 46_R to the cam bearing portions 50_R and the cam holder 51_R via the oiling holes 53_R. Further, an oil groove 54_R facing to the outer surface of the cam shaft 46_R is provided in the second cam bearing portion 50_R from the outermost end on the one end side of the cam shaft 46_R, and an oiling passage 55_R provided in the right cylinder head 24_R and the right cylinder block 23_R is communicated to the oil groove 54_R.

Each of the intake side cams 48_R and the exhaust side cams 49_R has an oiling hole (not shown) communicated to the oil passage 52_R in the cam shaft 46_R. Lubricating oil is thus also supplied to a slide-contact portion between each of the intake side cams 48_R and the exhaust side cams 49_R and the associated one of the valve lifters 47_R provided for each of the intake valves 36_L and the exhaust valves 37_L

On the lower side from the plane 38_R, the right cylinder head 24_R has a plurality of (for example, four) of through-holes 56_R which are spaced in the axial line direction of the cam shaft 46_R. Of the four through-holes 56_R, two are each disposed between adjacent ones of the combustion chambers 26_R. Fastening bolts 57_R for fastening the right cylinder head 24_R to the right cylinder block 23_R are to be inserted in the through-holes 57_R.

Each through-hole 56_R is adjacent, on one end side (right side in Fig. 9) of the cam shaft 46_R, to the associated one of the exhaust passages 35_R bypassing the ignition plugs 39_R provided for the combustion chambers 26_R. Such a through-hole 56_R has a positional relationship that a distance L4 between a center of the through-hole 56_R and a center C_R of the associated combustion chamber 26_R is larger than a value L3 ($_L3?_L4$). The value L3 is half a distance between the centers C_R of the adjacent ones of the combustion chambers 26_R.

On the upper side from the plane 38_R, the right cylinder head 24_R has a plurality (for example, four) of through-holes 58_R spaced in the axial line direction of the cam shaft 46_R. Of the four through-holes 58_R, two are each disposed between the adjacent ones of the combustion chambers 26_R. Fastening bolts 59_R for fastening the right cylinder head 24_R to the right cylinder block 23_R are to be inserted in the through-holes 58_R. Each through-hole 58_R, that is, fastening bolt 59_R is disposed at a position where it is partially covered with the cam shaft 46_R.

Referring particularly to Fig. 10, of the plurality (for example, four) of the through-holes 58_R, the through-hole 58_R disposed at the outermost end on the one end side of the cam shaft 46_R is provided in the cam bearing portion 50_R, disposed at the outermost end on the one end side of the cam shaft 46_R, of the four cam bearing portions 50_R. The oil groove 54_R is provided in

the cam bearing portion 50_R adjacent to the above-described cam bearing portion 50_R disposed at the outermost end on the one end side of the cam shaft 46_R.

Further, a distance L5 between a center of the through-hole 58_R disposed at the outermost end on the one end side of the cam shaft 46_R and the center C_R of the combustion chamber 26_R disposed at the outermost end on the one end side of the cam shaft 46_R is set to be smaller than the value L3 ($\frac{1}{2}$L3). The value L3 is, as described above, half the distance between the centers C_R of the adjacent ones of the combustion chambers 26_R.

A right head cover 60_R is fastened to the right cylinder head 24_R in such a manner that a valve system chamber 61_R for containing the cam shaft 46_R and the cam holder 51_R is formed between the right head cover 60_R and the right cylinder head 24_R. The valve system chamber 61_R is formed between the right head cover 60_R and the right cylinder head 24_R in such a manner as to be offset upwardly from the plane 38_R.

A cover portion 62_R is formed integrally with the right head cover 60_R. Portions, connected to the exhaust passages 35_R, of the exhaust pipes 41_R of the exhaust system 43_R and the ignition plugs 39_R disposed downwardly are covered from outside by the cover portion 62_R.

With respect to the intake passages 34_L and the exhaust passages 35_L provided in the left cylinder head 24_L and the intake passages 34_R and the exhaust passages 35_R provided in the right cylinder head 24_R as described above, the relative positional relationship between the intake passages 34_L and the exhaust passages 35_L along the axial line direction of the crank shaft 29 in the left cylinder head 24_L is set to be nearly equal to the relative positional relationship between the intake passages 34_R and the exhaust passages 35_R along the axial line direction of the crank shaft 29 in the right cylinder head 24_R.

A throttle body 63, an intake manifold 64 and an intake system 66 including fuel injection valves 65 provided for each of the combustion chambers 26_L and 26_R are disposed over a location between both the cylinder heads 24_L and 24_R. The intake manifold 64 is connected to the intake passages 34_L and 34_R of both the cylinder heads 24_L and 24_R.

Secondary air supply passages 44_L each of which is communicated to the exhaust passage 35_L are provided in the cylinder head 24_L and the cylinder block 23_L of the left engine block B_L, and secondary air supply passages 44_R each of which is communicated to the exhaust passage 35_R are provided in the cylinder head 24_R and the cylinder block 23_R of the right engine block B_R. The secondary air supply passages 44_L are connected to control valves (not shown) via check valves 45 provided in the cylinder block 23_L, and the secondary air supply passages 44_R are similarly connected to control valves (not shown) via check valves 45 provided in the cylinder block 23_R.

Referring particularly to Fig. 11, a transmission mechanism 68_L is provided between one end portion of the cam shaft 46_L on the left engine block B_L side and one end portion of the crank shaft 29. The transmission mechanism 68_L is adapted to reduce a rotational power of the crank shaft 29 to a half and transmit the reduced rotational power to the cam shaft 46_L. A transmission mechanism 68_R is provided between one end portion of the cam shaft 46_R on the right engine block B_R side and one end portion of the crank shaft 29. The transmission mechanism 68_R is adapted to reduce a rotational power of the crank shaft 29 to a half and transmit the reduced rotational power to the cam shaft 46_R.

The transmission mechanism 68_L (or 68_R) is configured such that an endless chain 71_L (or 71_R) is wound around a drive sprocket 69_L (or 69_R) fixed on the one end portion of the crank shaft 29 and a driven

sprocket 70_L (or 70_R) fixed on the one end portion of the cam shaft 46_L (or 46_R). As described above, each of the cylinder bores 21_R constituting the cylinder bore row 22_R on the right engine block B_R side is offset forwardly in the longitudinal direction of the motorcycle from each of the cylinder bores 21_L constituting the cylinder bore row 22_L on the left engine block B_L side by the first offset amount L1, and correspondingly, the transmission mechanism 68_R on the right engine block B_R side is offset forwardly in the longitudinal direction of the motorcycle from the transmission mechanism 68_L on the left engine block B_L side. In this case, a gap L6 between both the transmission mechanisms 68_L and 68_R is set to be smaller than the first offset amount L1 (L6 <L1).

A transmission chamber 72_L for containing the transmission mechanism 68_L is formed in the front end portion of the left engine block B_L along the longitudinal direction of the motorcycle in such a manner as to extend from the head cover 60_L to the crank case 27_L by way of the cylinder head 24_L and the cylinder block 23_L. To be more specific, one end of the transmission chamber 72_L faces to the valve system chamber 61_L and the other end thereof faces to the crank shaft 29. Similarly, a transmission chamber 72_R for containing the transmission mechanism 68_R is formed in the front end portion of the right engine block B_R along the longitudinal direction of the motorcycle in such a manner as to extend from the head cover 60_R to the crank case 27_R by way of the cylinder head 24_R and the cylinder block 23_R. To be more specific, one end of the transmission chamber 72_R faces to the valve system chamber 61_R and the other end thereof faces to one end of the crank shaft 29. Accordingly, the other end portions of both the transmission chambers 72_L and 72_R are commonly formed in such a manner as to face to the one end of the crank shaft 29. An opening 73 facing to the

other end portions of both the transmission chambers 72_L and 72_R is provided in the left and right crank cases 27_L and 27_R, and is covered with a lid member 74 fastened to the left and right crank cases 27_L and 27_R.

In a space on the other end side of the transmission chambers 72_L and 72_R, a pulse rotor 75 is fixed to the one end portion of the crank case 29 at a position outside both the sprockets 68_L and 68_R. A sensor 76 facing to the outer periphery of the pulse rotor 75 is mounted on one of the left and right crank cases 27_L and 27_R (left crank case 27_L in this embodiment). The sensor 76 is adapted to detect the passing of teeth provided on the outer periphery of the pulse rotor 75. In this way, the rotational position of the crank shaft 29 is detected by the sensor 76.

A pulse rotor 77 is fixed to the one end portion of one of the cam shafts 46_L and 46_R (cam shaft 46_L in this embodiment) at a position outside the driven sprocket 70_L. A sensor (not shown) for detecting the rotational position of the cam shaft 46_L is mounted to the left cylinder head 24_L in such a manner as to face to the outer periphery of the pulse rotor 77.

The crank shaft 29 is rotated in the rotational direction shown by an arrow 78 in Fig. 11. At the left side transmission mechanism 68_L, a chain tensioner 79_L is elastically, slidably in contact with the forward movement portion, that is, the lower side running portion of the chain 71_L running counterclockwise from the drive sprocket 69_L to the driven sprocket 70_L, and a chain guide 80_L is slidably in contact with the backward movement portion, that is, the upper side running portion of the chain 71_L running counterclockwise from the driven sprocket 70_L to the drive sprocket 69_L.

The chain tensioner 79_L is formed long along the running direction of the chain 71_L. One end portion of the chain tensioner 79_L is turnably supported by the bearing cap 32, which is closest to the transmission

mechanism 68_L among the plurality of bearing caps 32 for rotatably supporting the crank shaft 29 in co-operation of the plurality of journal walls 31, via a supporting shaft 81_L having the axial line parallel to the rotational axial line of the crank shaft 29. A tensioner lifter 82_L, which is in contact with an intermediate portion of the chain tensioner 79_L in the longitudinal direction while pressing the chain tensioner 79_L onto the chain 71_L, is mounted to the left cylinder block 23_L.

The chain guide 80_L is formed long along the running direction of the chain 71_L. One end portion of the chain guide 80_L is supported via a bolt 83_L on the journal wall 31 closest to the transmission mechanism 68_L; and an intermediate portion and the other end portion of the chain guide 80_L are in contact with and supported by the left cylinder block 23_L and the left cylinder head 24_L, respectively.

At the right side transmission mechanism 68_R, a chain tensioner 79_R is elastically, slidably in contact with the forward movement portion, that is, the upper side running portion of the chain 71_R running counterclockwise from the drive sprocket 69_R to the driven sprocket 70_R, and a chain guide 80_R is slidably in contact with the backward movement portion, that is, the lower side running portion of the chain 71_R running counterclockwise from the driven sprocket 70_R to the drive sprocket 69_R.

The chain tensioner 79_R is formed long along the running direction of the chain 71_R. One end portion of the chain tensioner 79_R is turnably supported by the journal wall 31, which is closest to the transmission mechanisms 68_L and 68_R among the plurality of the journal walls 31 formed integrally with the left crank case 27_L, via a supporting shaft 81_R having the axial line parallel to the rotational axial line of the crank shaft 29. A tensioner lifter 82_R, which is in contact with an

intermediate portion of the chain tensioner 79_R in the longitudinal direction while pressing the chain tensioner 79_R onto the chain 71_R, is mounted to the right cylinder block 23_R.

The chain guide 80_R is formed long along the running direction of the chain 71_R. One end portion of the chain guide 80_R is supported via a bolt 83_R on a supporting portion 84 formed integrally with the right crank case 27_R; and an intermediate portion and the other end portion of the chain guide 80_R are in contact with and supported by the right cylinder block 23_R and the right cylinder head 24_R, respectively.

The one end portion of the transmission chamber 72_L (or 72_R) for containing the transmission mechanism 68_L (or 68_R) is communicated to the valve system chamber 61_L (or 61_R), and the valve system chamber 61_L (or 61_R) is disposed on the upper side from the plane 38_L (or 38_R) containing the axial line of the crank shaft 29 and the axial lines of the cylinder bores 21_L (or 21_R). Accordingly, oil supplied from the interior of the valve system chamber 61_L (or 61_R) into the one end of the transmission chamber 72_L (or 72_R) can be introduced to the other end portion, facing to the one end of the crank shaft 29, of the transmission chamber 72_L (or 72_R). A return hole 85 for communicating the bottoms of the other end portions of both the transmission chambers 72_L and 72_R to the crank chamber 28 is provided in the left and right crank cases 27_L and 27_R.

Referring particularly to Fig. 12, a plurality of ribs 88 to be in contact with and connected to the plurality of journal walls 31 formed integrally with the left crank case 27_L are formed integrally with the right crank case 27_R in such a manner as to surround the bearing caps 32. The return hole 85 is formed in a region extending from the journal wall 31 facing to both the transmission chambers 72_L and 72_R among the plurality of journal walls 31 to the rib 88 in contact with and

connected to the above journal wall 31. To be more specific, the return hole 85 is composed of a recess 86 provided in the above journal wall 31 in such a manner as to be opened to the above rib 88 side and a recess 87 provided in the above rib 88 in such a manner as to be opened to the above journal wall 31 side.

The bearing cap 32 is, as described above, fastened to the journal wall 31 with the pair of bolts 33, and the return hole 85 is formed long along the fastening direction of the bearing cap 32 to the journal wall 31, that is, the axial line direction of the bolts 33.

The return hole 85 is formed between the crank cases 27_L and 27_R in such a manner as to be offset toward the left crank case 27_L side. To be more specific, of the recesses 86 and 87 constituting the return hole 85, the recess 86 provided in the journal wall 31 is long along the axial line direction of the bolts 33 than the recess 87 formed in the rib 88.

A mission case 90 is continued to the left and right engine blocks B_L and B_R in such a manner as to extend downwardly from the crank cases 27_L and 27_R and also extend rearwardly in the longitudinal direction of the motorcycle from the cylinder blocks 23_L and 23_R. Like the above-described return hole 85, a passage hole 89 is provided in such a manner as to extend from the bottom of the journal wall 31 disposed between the return hole 85 and the interior of the mission case 90 to the bottom of the rib 88 in contact with and connected to the journal wall 31. Accordingly, oil having been returned from the transmission chambers 72_L and 72_R into the crank chamber 28 via the return hole 85 is introduced in the mission case 90 by way of the passage hole 89.

As described above, oil in the valve system chamber 61_L and 61_R is returned to the crank chamber 28 side via the transmission chambers 72_L and 72_R on the one end sides of the cam shafts 64_L and 64_R. Here, since the cam

shafts 64_L and 64_R are disposed substantially in the horizontal direction, it may be desirable to allow the return of oil from the other end sides of the cam shafts 64_L and 64_R to the crank chamber 28 side in the valve system chambers 61_L and 61_R. To meet the above requirement, a return passage 91_L (or 91_R) having one end communicated to the interior of the valve system chamber 61_L (or 61_R) on the other end side of the cam shaft 64_L (or 64_R) and also having the other end communicated to the crank chamber 28 is provided in the left cylinder head 24_L (or right cylinder head 24_R) and the left cylinder block 23_L (or right cylinder block 23_R).

Referring particularly to Figs. 13 and 14, a water pump 94 including a pump shaft 95 directly connected to the crank case 29 is disposed on the back face of the mission case 90. A casing 96 of the water pump 94 is composed of a pump body 97 for rotatably supporting the pump shaft 95, and a pump cover 98 fastened to the pump body 97 in such a manner as to cover an impeller 99 fixed to the pump shaft 95.

The pump body 97 is formed integrally with the mission case 90. The pump cover 98 is fastened to the pump body 97 with a pump chamber 100 formed between the pump cover 98 and the pump body 97. The pump shaft 95 is rotatably supported by the pump body 97 in a state that one end thereof projects in the pump chamber 100. An engagement plate 95a to be engaged with an engagement recess 29a provided in the other end of the crank shaft 29 is projectingly provided at the other end of the pump shaft 95. That is to say, the one end side of the crank shaft 29 is connected to the cam shafts 64_L and 64_R via the transmission mechanisms 68_L and 68_R, while the other end side of the crank shaft 29 is directly connected to the pump shaft 95 of the water pump 94.

The impeller 99 is disposed in the pump chamber 100 and is fixed to the one end of the pump shaft 95. Over the impeller 99, a containing portion 101 communicated

to the central portion of the pump chamber 100 is formed in the upper portion of the pump cover 98.

A wax type thermostat 102, which is additionally provided on the water pump 94, is contained in the containing portion 101 in a state being held between the pump body 97 and the pump cover 98.

The thermostat 102 is of a known type, and includes a supporting plate 103 held between the pump body 97 and the pump cover 98, a thermostat valve 104, and a bypass valve 105.

A first suction port 106 opened to one end of the containing portion 101 is provided in the upper portion of the pump body 97 in such a manner as to be openable/closable by the thermostat valve 104, and a second suction port 107 opened to the other end of the containing portion 101 is provided in the pump cover 98 in such a manner as to be openable/closable by the bypass valve 105. A discharge port 108 for discharging cooling water discharged depending on rotation of the impeller 99 is provided in the pump cover 98. The discharge port 108 is communicated to the pump chamber 100.

A water jacket 109_L (or 109_R) is provided on the left cylinder block 23_L (or right cylinder block 23_R), and a water jacket 110_L (or 110_R) communicated to the water jacket 109_L (or 109_R) is provided on the cylinder block 23_L (or 23_R). The discharge port 108 of the water pump 94 is communicated to the water jackets 109_L and 109_R via cooling water supply pipes 111 connected to the left and right cylinder blocks 23_L and 23_R.

A cooling water discharge pipe 112_L (or 112_R) for discharge cooling water from the water jackets 110_L (or 110_R) is connected to the left cylinder block 24_L (or right cylinder head 24_R). The cooling water discharge pipes 112_L and 112_R are connected to the second suction port 107 of the water pump 94, and are also connected to inlets of radiators 113_L and 113_R, respectively.

The radiators 113_L and 113_R are disposed over the left and right engine blocks B_L and B_R, that is, both the cylinder bore rows 22_L and 22_R. The outlets of both the radiators 113_L and 113_R are connected to the first suction port 106 of the water pump 94.

According to such a cooling water circuit, in a state in which the temperature of cooling water is low before warming of the engine, the thermostat 102 closes the thermostat valve 104 and opens the bypass valve 105, so that cooling water discharged from the discharge port 108 of the water pump 94 is sucked from the water jackets 109_L, 110_L, 109_R and 110_R into the water pump 94 not by way of the radiators 113_L and 113_R. On the other hand, as the temperature of cooling water becomes higher along with termination of warming of the engine, the thermostat 102 opens the thermostat valve 104 and closes the bypass valve 105, so that cooling water discharged from the discharge port 108 of the water pump 94 is sucked from the water jackets 109_L, 110_L, 109_R and 110_R into the water pump 94 by way of the radiators 113_L and 113_R. That is to say, a bottom bypass type cooling water circuit using the thermostat 102 is formed among the water pump 94, the water jackets 109_L, 109_R, 110_L and 110_R and the radiators 113_L and 113_R.

A jiggle valve 114 for releasing air in the water pump 94 onto the first suction port 106 side is mounted on the upper portion of the supporting plate 103 of the thermostat 102 disposed over the impeller 99.

Referring to particularly to Fig. 13, a main shaft 115 linked with the crank shaft 29, a counter shaft 116 with a plurality of gear trains capable of being selectively established provided between the main shaft 115 and the counter shaft 116, and an output shaft 117 linked with the counter shaft 116 via a one-way clutch (not shown) are rotatably supported by the mission case 90. Each of the shafts 115, 116 and 117 has the axial line parallel to that of the crank shaft 29. The output

shaft 117 for transmitting a power to the rear wheel side of the motorcycle projects rearwardly from the back face of the mission case 90.

A shifter shaft 119 for axially movably supporting a plurality of shifters 118 for selectively establishing the gear trains between the main shaft 115 and the counter shaft 116 is supported by the mission case 90 at a position below and between the main shaft 115 and the counter shaft 116. A shift drum 120 for selectively moving one of the shifters 118 is supported by the mission case 90 at a position adjacent to the shifter shaft 119 in such a manner as to be rotatable on its axis.

A motor 121 having a rotational axial line parallel to the axial line of the crank shaft 29 is mounted on the back face of the mission case 90 at a position above and between the crank shaft 29 and the output shaft 117. An intermediate shaft 122 is supported by the mission case 90 at a position between the crank shaft 29 and the motor 121. A gear train (not shown), which allows transmission of a rotational power from the motor 121 to the crank shaft 29 but does not allow transmission of the power from the crank shaft 29 to the motor 121, is provided between the motor 121 and the crank shaft 29 with the intermediate shaft 122 interposed therebetween, so that the power of the motor 121 is transmitted to the crank shaft 29 upon start-up of the engine.

A power transmission mechanism 123 actuated upon backward movement is provided between the motor 121 and the output shaft 117. The mechanism 123 is adapted to transmit a rotational power from the motor 121 to the output shaft 117 on the basis of a driver's operation for backward movement and to rotate the output shaft 117 in the direction reversed to that upon forward movement. The power transmission mechanism 123 actuated for backward movement cuts off the power transmission from the output shaft 117 to the motor 121 upon operation not

for backward movement.

An electric generator 124 linked with the crank shaft 29 is mounted on the back face of the mission case 90 in parallel to the axial line of the crank shaft 29. A clutch 125 coaxial with the main shaft 115, which is capable of switching the connection/disconnection between the crank shaft 29 and the main shaft 115, is disposed on the back face of the mission case 90. That is to say, the electric generator 124 and the clutch 125 are disposed on the back face of the mission case 90 in parallel to the water pump 94 coaxial with the crank shaft 29.

An oil pump 126 connected to the main shaft 115 via a power transmission mechanism 128 such as a chain is provided in the lower portion of the mission case 90. Oil discharged from the oil pump 126 is supplied to respective portions to be lubricated of the engine main body E via an oil filter 127 (see Fig. 2) provided on the front surface side of the mission case 90. The oiling passages 55_L and 55_R provided in the left and right cylinder blocks 23_L and 23_R and the left and right cylinder heads 24_L and 24_R for introducing oil to portions to be lubricated of the cam shafts 46_L and 46_R are connected to the oil filter 127.

Referring again to Figs. 1 and 2, a body frame (not shown) of the motorcycle has steps 130_L and 130_R on which the driver's feet are to rest. The steps 130_L and 130_R are mounted on left and right portions positioned behind and below the left and right cylinder heads 24_L and 24_R of the engine main body E in such as manner as to project leftwardly and rightwardly therefrom. The inner end of each of the steps 130_L and 130_R is offset a distance L7 inwardly in the width direction of the motorcycle from the opening formed at the outer end of each of the exhaust passages 35_L and 35_R provided in the cylinder heads 24_L and 24_R.

To prevent the action of the driver's feet on the

steps 130_L and 130_R from being obstructed by the left and right cylinder heads 24_L and 24_R and the left and right head covers 60_L and 60_R, the lower rear corners thereof are cut off as shown by reference numeral 131.

Next, the function of this embodiment will be described. In the horizontally-opposed type multi-cylinder (for example, six cylinder) engine, a pair of left and right cylinder bore rows 22_L and 22_R disposed on both the sides of the crank shaft 20 extending substantially in the horizontal direction; the left cylinder bore row 22_L (or right cylinder bore row 22_R) is composed of a plurality (for example, three) of the cylinder bores 21_L (or 21_R) disposed in parallel; and the cam shaft 46_L (or 46_R) corresponding to the cylinder bore row 22_L (or 22_R) is disposed on the upper side from the plane 38_L (or 38_R) containing the axial lines of the cylinder bores 21_L (or 21_R) and the axial line of the crank shaft 29. Accordingly, the valve system mechanism containing the cam shaft 46_L (or 46_R) is offset upwardly from the axial lines of the cylinder bores 21_L (or 21_R), so that the cylinder head 24_L (or 24_R) can be formed in such a manner as to ensure a space under the portion corresponding to the valve system mechanism. In other words, a relatively large space can be ensured under the cylinder head 24_L (or 24_R).

In the case of mounting the horizontally-opposed type multi-cylinder engine on the motorcycle in such a manner that the axial line of the crank shaft 29 extends along the longitudinal direction of the motorcycle and the cylinder heads 24_L and 24_R project on both sides of the motorcycle in the width direction, it is possible to ensure a sufficient space for allowing the driver's feet to rest at a position under the cylinder heads 24_L and 24_R and to set a bank angle a of the motorcycle at a relatively large value.

The pairs of the intake valves 36_L (or 36_R) and the exhaust valves 37_L (or 37_R), each pair being disposed for

each cylinder bore 21_L (or 21_R), that is, for each combustion chamber 26_L (or 26_R), are disposed in parallel in such a manner as to be offset upwardly from the plane 38_L (or 38_R), and are directly opened/closed by the intake side cams 48_L (or 48_R) and the exhaust cams 49_L (or 49_R) provided on the cam shaft 46_L (or 46_R). Accordingly, the valve system mechanism for driving the intake valves 36_L (or 36_R) and the exhaust valves 37_L (or 37_R) can be significantly simplified. Also since the cam shafts 46_L and 46_R are disposed for the cylinder bore rows 22_L and 22_R, respectively, the cylinder heads 24_L and 24_R can be made compact.

Since the intake valves 36_L (or 36_R) and the exhaust valves 37_L (or 37_R) are disposed in the cylinder head 24_L (or 24_R) in such a manner as to be tiled at an acute angle with respect to the plane 38_L (or 38_R), it is possible to form the ceiling wall surface of each of the combustion chambers 26_L (or 26_R) into a pent-roof or semi-spherical shape and hence to set the S/V ratio at a relatively small value.

On the opposed side to the disposition side of the intake valves 36_L (36_R) and the exhaust valves 37_L (or 37_R) with respect to the plane 38_L (or 38_R), that is, on the lower side from the plane 38_L (or 38_R), the ignition plugs 39_L (39_R) each facing to the combustion chamber 26_L (or 26_R) are mounted to the cylinder head 24_L (or 24_R). In this case, since the intake valves 36_L (or 36_R) and the exhaust valves 37_L (or 37_R) are tilted at an acute angle with respect to the plane 38_L (or 38_R), it is possible to ensure a relatively wide space on the opposed side to the disposition side of the intake valves 36_L (or 36_R) and the exhaust valves 37_L (or 37_R) with respect to the plane 38_L (or 38_R), that is, the lower side from the plane 38_L (or 38_R), and hence to easily make the ignition plugs 39_L (or 39_R) face to the central portions of the combustion chambers 26_L (or 26_R) while avoiding the interference with the intake valves

36_L (or 36_R) and the exhaust valves 37_L (or 37_R) and to increase the degree of freedom in disposition of the ignition plugs 39_L (or 39_R).

The ignition plugs 39_L (or 39_R) are tilted at an acute angle with respect to the plane 38_L (or 38_R). With respect to the tilting angle of the ignition plugs 39_L (or 39_R), since the intake valves 36_L (or 36_R) and the exhaust valves 37_L (or 37_R) are tiled at an acute angle with respect to the plane 38_L (or 38_R), it is possible to make the ignition plugs 39_L (or 39_R) face to the central portions of the combustion chambers 26_L (or 26_R) while avoiding the interference with the cam shafts 46_L (or 46_R) without setting the tilting angle of the ignition plugs 39_L (or 39_R) at a large value.

The cylinder head 24_L (or 24_R) includes the intake passages 34_L (or 34_R) opened to the side surface of the cylinder head 24_L (or 24_R) on the upper side from the plane 38_L (or 38_R), and also includes the exhaust passages 35_L (or 35_R) opened to the other side surface of the cylinder head 24_L (or 24_R) on the lower side from the plane 38_L (or 38_R). That is to say, since the intake valves 34_L (or 34_R) and the exhaust valves 35_L (or 35_R) are provided in such a manner as to be opened to the side surfaces of the cylinder head 24_L (or 24_R) on both sides of the plane 38_L (or 28_R), it is easy to connect the intake system 66 and the exhaust system 43_L (or 43_R) to the cylinder head 24_L (or 24_R).

On the projection chart perpendicular to the axial lines of the cylinder bores 21_L (or 21_R), the intake passages 34_L (or 34_R) are provided in the cylinder head 24_L (or 24_R) in such a manner as to cross the plane 38_L (or 38_R) substantially at right angles. That is to say, since the intake valves 34_L (or 34_R) extend substantially in a straight line while being relatively gently curved to the combustion chambers 26_L (or 26_R), it is possible to reduce the intake resistance at the intake passages 34_L (or 34_R) and hence to enhance the charging

efficiency.

The exhaust passages 35_L (or 35_R) are provided in the cylinder head 24_L (or 24_R) in such a manner as to be curved or swelled to the one end side of the cam shaft 46_L (or 46_R), that is, the front side of the motorcycle in order to bypass the ignition plugs 39_L (or 39_R). As a result, the flow resistance in the exhaust passages 35_L (or 35_R) is larger than that of the intake passages 34_L (or 34_R); however, there arises no problem because the exhaust gas from the combustion chambers 26_L (or 26_R) is pressurized.

Since the cam shaft 46_L (or 46_R) is disposed over the axial line of the cylinder bore row 22_L (or 22_R) and also the exhaust passages 35_L (or 35_R) bypassing the ignition plugs 39_L (or 39_R) are curved to the front side, it is easy to ensure a space for allowing the driver's feet to rest at a position behind and below the horizontally-opposed type engine mounted on the motorcycle.

While the exhaust passages 35_L (or 35_R) are downwardly opened to the lower side surface of the cylinder head 24_L (or 24_R), the ignition plugs 39_L (or 39_R) are also mounted to the cylinder head 24_L (or 24_R) in such a manner as to be tilted downwardly. Accordingly, in the horizontally-opposed type multi-cylinder engine mounted on the motorcycle, it is possible to improve the appearance characteristic of the ignition plugs 39_L (or 39_R) and their neighborhoods, to easily discharge water having permeated in the vicinities of the ignition plugs 39_L (39_R) on the outer surface side of the cylinder head 24_L (or 24_R), and to easily lay out the exhaust pipes 41_L (41_R) connected to the exhaust passages 35_L (or 35_R).

Further, since the cover portion 62_L (or 62_R) for covering the ignition plugs 29_L (or 29_R) from outside is formed integrally with the left head cover 60_L (or right head cover 60_R) which is connected to the left cylinder

head 24_L (or right cylinder head 24_R) with the valve system chamber 61_L (or 61_R) for containing the cam shaft 46_L (46_R), it is possible to further improve the appearance of the ignition plugs 39_L (or 39_R) and their neighborhoods.

Since the exhaust passages 35_L (or 35_R) are provided in the cylinder head 24_L (or 24_R) in such a manner as to be tilted to the central side of the motorcycle in the width direction and to be downwardly opened and thereby the exhaust pipes 41_L (or 41_R) connected to the exhaust passages 35_L (or 35_R) can be disposed near the center portion of the motorcycle in the width direction, it is possible to loosen the restriction of the bank angle a of the motorcycle due to the exhaust pipes 41_L (or 41_R) and hence to easily ensure the above bank angle a.

Further, since the exhaust pipes 41_L (or 41_R) are tilted in such a manner as to get closer to the central side of the motorcycle in the width direction as being separated apart downwardly from the cylinder head 24_L (or 24_R) and are connected to the exhaust passages 35_L (or 35_R), it is possible to further loosen the restriction of the bank angle a of the motorcycle due to the exhaust pipes 41_L (or 41_R) and hence to more easily ensure the above bank angle a.

Since the exhaust valves 37_L (37_R) are disposed on the upper side from the plane 38_L (or 38_R) while the exhaust passages 35_L (or 35_R) are opened to the bottom surface of the cylinder head 24_L (or 24_R), it is possible to make relatively large a distance between each of the combustion chambers 26_L (or 26_R) and the opening end of the associated one of the exhaust passages 35_L (or 35_R) opened to the bottom surface of the cylinder head 24_L (or 24_R), and to make relatively gentle the curving of the exhaust passages 35_L (35_R) within the plane perpendicular to the axial line of the crank shaft 29 although the exhaust passages 35_L (or 35_R) are opened while being tilted to the central side of the motorcycle in the

width direction and hence to suppress the increase in exhaust resistance.

The cover portion 62_L (or 62_R) formed integrally with the left head cover 60_L (right head cover 60_R) has a function of covering connecting portions of the exhaust passages 35_L (or 35_R) to the exhaust pipes 41_L (or 41_R) from outside. This makes it possible to improve the appearance characteristics of the connecting portions of the exhaust passages 35_L (or 35_R) to the exhaust pipes 41_L (or 41_R). Further, since the exhaust pipes 41_L (or 41_R) are separated apart from the cover portion 62_L (or 62_R) as being directed downwardly, even if the head cover 60_L (or 60_R) is made from a synthetic resin, it is possible to avoid occurrence of thermal degradation of the cover portion 62_L (or 62_R).

With respect to the intake passages 34_L and the exhaust passages 35_L provided in the left cylinder head 24_L and the intake passages 34_R and the exhaust passages 35_R provided in the right cylinder head 24_R, the relative positional relationship between the intake passages 34_L and the exhaust passages 35_L along the axial line direction of the crank shaft 29 is set to be nearly equal to the relative positional relationship between the intake passages 34_R and the exhaust passages 35_R along the axial line direction of the crank shaft 29. This makes it possible to simplify the structures of the intake system 66 and the exhaust systems 43_L and 43_R.

To fasten the cylinder head 24_L (or 24_R) to the cylinder block 23_L (or 23_R), the cylinder head 24_L (or 24_R) has, on the lower side from the plane 38_L (or 38_R), a plurality of the through-holes 56_L (56_R) spaced in the axial direction of the cam shaft 46_L (or 46_R). The fastening bolts 57_L (or 57_R) are to be inserted in the through-holes 56_L (or 56_R). Further, each through-hole 56_L (or 56_R) is adjacent, on one end side of the cam shaft 46_L (or 46_R), to the associated one of the exhaust passages 35_L (or 35_R) bypassing the ignition plugs 39_L

(or 39_R) provided for the combustion chambers 26_L (or 26_R). Such a through-hole 56_L (or 56_R) has a positional relationship that a distance L4 between a center of the through-hole 56_L (or 56_R) and a center C_L (or C_R) of the associated combustion chamber 26_L (or 26_R) is larger than a value L3. The value L3 is half a distance between the centers C_L (or C_R) of the adjacent ones of the combustion chambers 26_L (or 26_R). This makes it possible to make relatively small the curving of the exhaust passages 35_L (or 35_R) bypassing the ignition plugs 39_L (or 39_R), and hence to prevent the flow resistance of the exhaust passages 35_L (or 35_R) from being excessively increased.

On the disposition side of the intake valves 36_R and the exhaust valves 37_R with respect to the plane 38_R, the right cylinder head 24_R has a plurality of the through-holes 58_R which are spaced in the axial line direction of the cam shaft 46_R. Of the plurality of the through-holes 58_R, the central side through-holes 58_R are each disposed between the adjacent ones of the combustion chambers 26_R. A distance L5 between a center of the through-hole 58_R disposed at the outermost end on the one end side of the cam shaft 46_R and the center C_R of the combustion chamber 26_R disposed at the outermost end on the one end side of the cam shaft 46_R is set to be smaller than the value L3. The value L3 is, as described above, half the distance between the centers C_R of the adjacent ones of the combustion chambers 26_R. Accordingly, the end portion of the cylinder head 24_R on the one end side of the cam shaft 46_R can be made as close to the center C_R of the combustion chamber 26_R disposed at the outermost end on the curved side of the exhaust passages 35_R bypassing the ignition plugs 39_R as possible. This makes the length of the cylinder head 24_R along the axial direction of the cam shaft 46_R as small as possible.

The cam shaft 46_L (or 46_R) is rotatably supported at a plurality of locations spaced in the axial direction

of the cam shaft 46_L (or 46_R) by the cam bearing portions 50_L (or 50_R) provided on the cylinder head 24_L (or 24_R) and the cam holder 51_L (or 51_R) fastened to the cam bearing portions 50_L (or 50_R). The transmission mechanism 68_L (or 68_R) for reducing a rotational power of the crank shaft 29 to a half and transmitting the reduced rotational power to the cam shaft 46_L (or 46_R) is provided between the crank shaft 29 and the cam shaft 46_L (or 46_R). The oil passage 52_L (or 52_R) capable of supplying oil from the oiling passage 55_L (or 55_R) provided in the cylinder head 24_L (or 24_R) and the cylinder block 23_L (or 23_R) is provided in the cam shaft 46_L (or 46_R). On the left cylinder head 24_L side, oil is supplied from the oil groove 54_L provided in the cam bearing portion 50_L disposed at the outermost end on the one end side of the cam shaft 46_L into the oil passage 52_L in the cam shaft 46_L via the oiling hole 53_L formed in the cam shaft 46_L. On the right cylinder head 24_R side, the oil groove 54_R for supplying oil into the oil passage 52_R in the cam shaft 46_R via the oiling hole 53_R formed in the cam shaft 46_R is formed in the cam bearing portion 50_R which is provided in the cylinder head 24_R correspondingly to the combustion chamber 26_R closest to the transmission mechanism 68_R among the plurality of combustion chambers 26_R disposed in the axial direction of the cam shaft 46_R.

With this disposition of the oil groove 54_R, it is possible to supply oil into the oil passage 52_R in the cam shaft 46_R without restriction of the disposition of the fastening bolts 57_R and 59_R for fastening the right cylinder head 24_R to the right cylinder block 23_R.

The cam bearing portion 50_R closest to the transmission mechanism 68_R among the plurality of the cam bearing portions 50_R provided on the right cylinder head 24_R has the through-hole 58_R into which the fastening bolt 59_R among the fastening bolts 57_R and 59_R for fastening the cylinder head 24_R to the cylinder block 23_R

is to be inserted. As a result, the fastening bolt 59_R between the transmission mechanism 68_R and the combustion chamber 26_R is made as close to the combustion chamber 26_R as possible, so that it is possible to shorten the length of the cylinder head 24_R along the axial line direction of the cam shaft 46_R.

The transmission mechanism 68_R corresponding to the cam shaft 46_R on the right cylinder head 24_R side is offset forwardly along the axial line direction of the crank shaft 29 from the transmission mechanism 68_L corresponding to the cam shaft 46_L on the left cylinder head 24_L. In other words, the outermost end on the one end side of the cam shaft 46_R is offset forwardly from that of the cam shaft 46_L, and the transmission mechanism 68_R is connected to the outermost end on the one end side of the cam shaft 46_R. The above through-hole 58_R and the above oil groove 54_R are provided in two of the plurality of the cam bearing portions 50_R provided on the cam shaft 46_R. Accordingly, it is possible to shorten the length between the transmission mechanism 68_R and the combustion chamber 26_R and hence to more effectively shorten the length of the multi-cylinder engine along the axial line direction of the cam shaft 46_L (or 46_R).

The pair of the cylinder bore rows 22_L and 22_R are offset from each other in the axial line direction of the crank shaft 29, and both the transmission mechanism 68_L and 68_R are disposed in such a manner that the gap L6 therebetween is smaller than the first offset amount L1 between the cylinder bore rows 22_L and 22_R. Accordingly, it is possible to set the gap between both the transmission mechanisms 68_L and 68_R at a smaller value, and hence to make smaller the length of the engine main body E along the axial line direction of the cam shaft 46_L (46_R).

Further, since both the transmission mechanism 68_L and 68_R are provided between the one end portion of the crank shaft 29 and the one end portion of the cam shaft

46_L and between the one end portion of the crank shaft 29 and the one end portion of the cam shaft 46_R, respectively, it is possible to more freely set the gap between both the transmission mechanisms 68_L and 68_R.

The outer end opening of each of the exhaust passages 35_L (or 35_R) opened to the bottom surface of the left cylinder head 24_L (or right cylinder head 24_R) is offset toward the one end side of the cam shaft 46_L (or 46_R), that is, toward the transmission mechanism 68_L (or 68_R) from the center C_L (or C_R) of the associated one of the combustion chambers 26_L (or 26_R). Accordingly, the exhaust systems 43_L and 43_R respectively connected to the exhaust passages 35_L and 35_R can be disposed by making effective use of the space between both the transmission mechanisms 68_L and 68_R, so that the entire engine including the exhaust systems 43_L and 43_R can be made compact.

Since both the transmission mechanisms 68_L and 68_R are disposed on the front portion of the engine main body E, a relatively large space is formed at a location positioned behind and below the left and right cylinder heads 24_L and 24_R, the steps 130_L and 130_R on which the driver's feet are to rest can be disposed behind the left and right cylinder heads 24_L and 24_R without any difficulty. Also since the inner end portion of each of the steps 130_L and 130_R is offset inwardly from the outer end opening of each of the exhaust passages 35_L and 35_R in the width direction of the motorcycle, the projecting amounts of the steps 130_L and 130_R in the width direction of the motorcycle is made as small as possible, so that the restriction of the steps 130_L and 130_R to the bank angle a can be suppressed.

The transmission mechanism 68_L (or 68_R) performs power transmission using the chain 71_L (or 71_R). The transmission chamber 72_L (72_R) having one end communicated to the valve system chamber 61_L (or 61_R) and the other end facing to the one end of the crank shaft

29 and containing the transmission mechanism 68_L (or 68_R) extends from the head cover 60_L (or 60_R) to the crank case 27_L (or 27_R) via the cylinder head 24_L (or 24_R) and the cylinder block 23_L (or 23_R). The other end of the transmission chamber 72_L (or 72_R) is communicated to the crank chamber 28.

Unlike a belt-type transmission mechanism, the transmission chamber 72_L (or 72_R) containing the transmission mechanism 68_L (or 68_R) allows oil to flow therethrough. Accordingly, it is possible to eliminate the necessity of provision of any means for preventing leakage of oil from the crank case 27_L (or 27_R) side onto the transmission chamber 72_L (or 72_R) side, and more specifically, the necessity of provision of a seal structure on the crank case 27_L (or 27_R), and hence to make the engine compact.

Further, since the cam shaft 46_L (or 46_R) is disposed over the crank shaft 29, oil in the valve system 61_L (or 61_R) is allowed to flow onto the crank shaft 29 side at the lower level through the transmission chamber 72_L (or 72_R). As a result, this makes it easy to return the oil in the valve system chamber 61_L (or 61_R) to the crank case 27_L (or 27_R) side.

To communicate the bottom portions of the other ends of the transmission chambers 72_L and 72_R into the crank chamber 28, the return hole 85 is provided in the left and right crank cases 27_L and 27_R. Accordingly, it is not required to provide oil return passages specialized for the cylinder blocks 23_L and 23_R and the cylinder heads 24_L and 24_R for returning oil from at least the transmission chambers 72_L and 72_R into the crank chambers 28, and correspondingly the cylinder blocks 23_L and 23_R and the cylinder blocks 24_L and 24_R can be made compact and reduced in weight.

The crank shaft 29 is rotatably supported by a plurality of the journal walls 31 formed integrally with the left crank case 27_L and a plurality of bearing caps

32 fastened to the journal walls 31. The return hole 85 is formed long along the fastening direction of the bearing caps 32 to the journal walls 31. Accordingly, it is possible to make relatively wide the opening area of the return hole 85 without reducing the supporting rigidity of the crank shaft 29, and hence to enhance the return characteristic of oil into the crank chamber 28.

The return hole 35 is formed in both the left and right crank cases 27_L and 27_R in such a manner as to be offset to the left crank case 27_L side. Accordingly, it is possible to make larger the opening area of the return hole 85 avoiding a reduction in rigidity of the crank case on which the journal walls 31 are not integrally formed, that is, the right crank case 27_R, and hence to further enhance the return characteristic of oil.

In the transmission mechanism 68_L provided between the left side cam shaft 46_L and the crank shaft 29, the chain tensioner 79_L extending along the running direction of the chain 71_L is elastically, slidably in contact with the chain 71_L. The one end of the chain tensioner 79_L in the longitudinal direction is turnably supported by the bearing cap 32 closest to the transmission mechanism 68_L among a plurality of the bearing caps 32. With this configuration, it is possible to moderate the restriction in the rotatably supporting position of the chain tensioner 79_L and to certainly confine the behavior of the chain 71_L by setting the length of the chain tensioner 79_L at a relatively large value.

Since the transmission mechanism 68_L is provided between the one end portion of the cam shaft 46_L and the one end portion of the crank shaft 29, it is not required to take into account the disposition of the rotatably supporting portion of the chain tensioner 79_L at a position where the chain tensioner 79_L does not interfere with a crank weight of the crank shaft 29. This makes it possible to simply set the rotatably

supporting position of the chain tensioner 79_L.

Since one end of the chain tensioner 79_L for the transmission mechanism 68_L on the cylinder block 23_L side on which the journal walls 31 are integrally formed is rotatably supported by the bearing cap 32 closest to the transmission mechanism 68_L, it is possible to simply set the rotatably supporting position of the chain tensioner 79_L by making effective use of one of the bearing caps 32 necessarily provided for the horizontally-opposed type multi-cylinder engine.

The pump shaft 95 of the water pump 94 is directly connected to the other end of the crank shaft 29 with its one end side connected to both the transmission mechanisms 68_L and 68_R, that is, the rear end of the crank shaft 29 along the longitudinal direction of the motorcycle, and the water pump 94 is directly driven by the crank shaft 29. Accordingly, it is possible to eliminate the necessity of provision of a gear, a chain, a belt, etc. required for driving the conventional water pump, and hence to simplify the drive mechanism of the water pump 94.

The pulse rotor 75 for detecting a rotational position of the crank shaft 29 is fixed to the one end portion of the crank shaft 29. By use of the pulse rotor 75, it is possible to easily detect a rotational position of the crank shaft 29 with no obstruction by the water pump 94.

Since the water pump 94 is disposed on the rear side in the longitudinal direction of the motorcycle, a piping system for cooling water, connected to the water pump 94, can be disposed at an inconspicuous position.

Since the radiators 113_L and 113_R are respectively disposed over both the engine blocks B_L and B_R, that is, over both the cylinder bore rows 22_L and 22_R, pipes for cooling water between the engine and both the radiators 113_L and 113_R made nearly equal on the left and right sides or even shorter.

Since the electric generator 124 and the clutch 125 are disposed in parallel to the water pump 94, it is not required to increase the length of the crank shaft 29 for disposing the electric generator 124 and the clutch 125 in spite of the fact that the water pump 94 is directly driven by the crank shaft 29, and accordingly, it is possible to make compact the engine in the axial direction of the crank shaft 29.

The casing 96 of the water pump 94 is composed of the pump body 97 for rotatably supporting the pump shaft 95, and the pump cover 98 connected to the pump body 97 in such a manner as to cover the impeller 99 fixed to the pump shaft 95. The thermostat 102 held between the pump body 97 and the pump cover 98 is contained in the containing portion 101 formed in the pump cover 98. As a result, in the case of additionally providing the thermostat 102 in the water pump 94, it is possible to reduce the number of parts, and hence to reduce the cost and weight and also reduce the number of the assembling steps.

The first suction port 106 opened to one end of the containing portion 101 is provided in the pump body 97 in such a manner as to be communicated to the radiators 113_L and 113_R, and the second suction port 107 opened to the other end of the containing portion 101 for introducing water from the engine not by way of the radiators 113_L and 113_R is provided in the pump cover 98. The thermostat 102 having the thermostat valve 104 for opening/closing the first suction port 106 and the bypass valve 105 for opening/closing the second suction port 107 is contained in the containing portion 101. Accordingly, when the temperature of cooling water is low, the thermostat valve 104 is closed and the bypass valve 105 is opened, while as the temperature of cooling water is increased, the thermostat valve 104 is opened and the bypass valve 105 is closed. In this way, the bottom-bypass type cooling water circuit can be simply

obtained.

Since the discharge port 108 for discharging cooling water discharged depending on rotation of the impeller 99 is provided in the pump cover 98, it is possible to simply obtain a circuit for introducing cooling water from the water pump 94.

Since the thermostat 102 is disposed over the impeller 99, it is possible to certainly release air in the water pump 94 by means of the jiggle valve 114 of the thermostat 102.

While the embodiment of the present invention has been described in detail, the present invention is not limited thereto, and it is to be understood that many changes in design may be made without departing from the scope of the claims.

Claims

1. An engine in which combustion chambers are formed between pistons slidably fitted in cylinder bores provided in a cylinder block and a cylinder head;

a cam shaft is linked with intake valves and exhaust valves for respectively opening/closing intake passages and exhaust passages which are provided in said cylinder head in such a manner as to be communicated to said combustion chambers; and

a transmission mechanism for reducing a rotational speed of a crank shaft to a half and transmitting the reduced rotational speed to said cam shaft is provided between said crank shaft and said cam shaft; wherein

said intake valves and said exhaust valves are disposed in parallel at positions offset to one side from a plane passing through the axial lines of said cylinder bores and the axial line of said crank shaft; and

cams for directly opening/closing said intake valves and said exhaust valves are provided on said cam shaft which is disposed in parallel to said crank shaft in such a manner as to common to said intake valves and said exhaust valves.

2. An engine according to claim 1, wherein on the opposed side to the disposition side of said intake valves and said exhaust valves with respect to said plane, ignition plugs are mounted on said cylinder head in such a manner as to face to the central portions of said combustion chambers.

3. An engine according to claim 1, wherein said intake passages and said exhaust passages are opened to side surfaces of said cylinder head on both sides of said plane, respectively.

4. An engine according to claim 3, wherein of said intake passages and said exhaust passages, said passages opened to the side surface of said cylinder head on the opposed side to the disposition side of said intake valves and said exhaust valves with respect to said plane are curved and swelled on one end side of said cam shaft in such a manner as to bypass said ignition plugs which are mounted in said cylinder head in such a manner as to face to said combustion chambers.

5. An engine according to claim 4, wherein on the opposed side to the disposition side of said intake valves and said exhaust valves with respect to said plane, said cylinder head has a plurality of through-holes including those each of which is disposed at the corresponding portion between the adjacent combustion chambers, said plurality of through-holes being arranged at intervals in the axial direction of said cam shaft in such a manner as to allow fastening bolts for fastening said cylinder head to said cylinder block to pass therethrough; and

a distance between a center of one of said through-hole adjacent to said passages bypassing said ignition plugs on the one side of said cam shaft and a center of one of said combustion chambers associated with said passage is set to be larger than half of a distance between the centers of the adjacent ones of said combustion chambers.

6. An engine according to claim 4, wherein on the disposition side of said intake valves and said exhaust valves with respect to said plane, said cylinder head has a plurality of through-holes including those each of which is disposed between adjacent ones of said combustion chambers, said plurality of through-holes being spaced at intervals in the axial direction of said cam shaft in such a manner as to allow fastening bolts

for fastening said cylinder head to said cylinder block; and

a distance between a center of one of said through-holes disposed at the outermost end on the one end side of said cam shaft and the center of one of said combustion chambers disposed at the outermost end on the one end side of said cam shaft is set to be smaller than a half of a distance between the centers of the adjacent ones of said combustion chambers.

7. An engine according to claim 2, wherein the axial lines of said cylinder bores are disposed substantially in the horizontal direction;

a valve system chamber is formed between said cylinder head and a head cover in such a manner as to contain said cam shaft offset upwardly from said plane;

one end of a transmission chamber for containing said transmission mechanism is communicated to said valve system chamber, said transmission mechanism being configured such that an endless chain is wound around a drive sprocket fixed on the one end of said crank shaft and a driven sprocket fixed on the one end of said cam shaft; and

the lower portion of the other end of said transmission chamber is communicated to said crank shaft.

8. An engine according to claim 4, wherein said engine is mounted in a vehicle in such a manner that a plurality of said cylinder bores are disposed in parallel with the axial lines thereof extending substantially in the horizontal direction; a pair of cylinder bore rows are oppositely disposed on both the sides of said crank shaft; a plurality of said intake valves and a plurality of said exhaust valves are disposed in parallel in such a manner as to be offset upwardly from said plane for each of said cylinder bore

rows; and the one end of said crank shaft in the axial direction is disposed on the front side of said vehicle.

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Application No:	GB 9923523.6	**Examiner:**	John Twin
Claims searched:	1 to 8	**Date of search:**	20 December 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): F1B (B2P1A1, B2P1A4)

Int Cl (Ed.6): F01L 1/047, 1/053

Other: online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US 4223647	(Renault)	1
X	US 3989016	(General Motors)	1

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